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MARCH 2013

**DRONES ARE
WATCHING YOU**

NATIONAL GEOGRAPHIC

AMERICA STRIKES OIL

*The Promise
and Risk of*

FRACKING

GAS FLARES AT A
WELL IN WESTERN
NORTH DAKOTA.



Indefatigable Island Tortoise (*Chelonoidis nigra porteri*)
Size: Carapace up to 130 cm (51.2 inches) **Weight:** Up to 272.2 kg (600 lbs) **Habitat:** Found only on Santa Cruz, the second largest of the Galapagos Islands **Surviving number:** Estimated at 3,300 adults




Photographed by Christian Ziegler

WILDLIFE AS CANON SEES IT

On and on. The Indefatigable Island tortoise can live for more than 150 years, and is able to survive for months without food and water. Over the years, this gentle giant of the Galapagos has developed a symbiotic relationship with other animals that share its home, including birds that feed on the ticks attracted to the tortoise. But it has not been as fortunate in its relationship with humans, who harvested the tortoise for meat

and oil for several centuries and also introduced species like rats and goats that destroy its young and compete with it for food. The question is, How long can the tortoise go on?

As we see it, we can help make the world a better place. Raising awareness of endangered species is just one of the ways we at Canon are taking action—for the good of the planet we call home. Visit canon.com/environment to learn more.



A sailor at Fort Pickett in Virginia launches the Puma UAV, a drone designed to gather intelligence. Its TV camera sends video back to a laptop.

JOE McNALLY

March 2013

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North Dakota has thousands of wells and temporary laborers—all because of fracking. What's the cost to the land and its people?

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They count ladybugs, whale sharks, elephants.

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Watch the flowers unfurl by moonlight.



Bonobos **Interactive Art**

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Risk Taker **Video**

Meet a biologist who really dives into her job.



On the Cover Natural gas escapes from underground and flares on one of North Dakota's oil fields. The distant rig is near the intersection of Highway 2 and Highway 85, north of Williston. The picture was taken on June 2, 2012.

Photo by Eugene Richards

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Taking Chances

Flip a coin. Heads or tails? The odds are fifty-fifty either way. Make a bet and take your chances. A gamble is just that—a decision that has risk attached to it. Someone wins. But someone loses. When it comes to fracking—the process of extracting otherwise unreachable oil and natural gas by driving fresh water mixed with other substances, some toxic, into layers of rock—the bets become less mathematically clear.

In this month's cover story, "The New Oil Landscape," writer Edwin Dobb lays out the choices. On one side of the equation are abundant fossil fuels, less dependence on foreign sources, and the kind of economic prosperity that comes with jobs. On the other side is the possibility of contaminated groundwater, environmental degradation, and what Dobb calls a loss of prairie values—"silence, solitude, serenity."

All this is happening on the North Dakota plains. I know them well. As a graduate student at the University of Minnesota, I would make the drive from my home in Oregon to Minneapolis straight through that corner of North Dakota where the Missouri hangs a right turn. It was the same territory that Lewis and Clark explored in 1805. Later, as a photographer on a story about Sacagawea, I gave that landscape an even closer look. It is a land of long horizons, fragrant with wild mint and freshly cut alfalfa, and wheat fields tousled by the constant breath of wind. I think about what that landscape was once like and how it's changing. I hope our readers will think about that too.



Neighbors near Tioga, North Dakota, gather to protest and pray about local oil development.

PHOTO: EUGENE RICHARDS

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Vikings and Native Americans

The disappearance of the Dorset people coincides with the late 14th-century decline of Viking settlement in Greenland.

- ▶ Deprived of the established Norse trade, might the Dorset simply have melted away and merged with surrounding local cultures? This would have left no trace or clue to their sudden disappearance.

ALAN DEAN FOSTER
Prescott, Arizona

Heather Pringle writes of the research that Patricia Sutherland has undertaken in her digs on Baffin Island and elsewhere, but nowhere is credit given to the man who had the good sense to study samples of the odd pieces of string that he found when he was excavating abandoned Dorset sites. A Roman Catholic missionary who remains unnamed! What a terrible slight on his intelligence and sense.

PETER McDONOUGH
Boston, Massachusetts

The missionary's name was Father Guy Mary-Rousselière.

Let's do away with Columbus Day and institute Leif Eriksson Day instead. Vikings came to North America before Columbus did, and he never set foot on the continent. He only "found" some islands in the Caribbean.

DIANN LANDAU
Lovettsville, Virginia

The introduction of illnesses previously unknown to the Dorset could have wiped them out as the illnesses were introduced from clan to clan during hunting and trading.

TONY FRAZIER
Hoquiam, Washington

The most tantalizing implication of Heather Pringle's article is the ethnic linkages she made to the enigmatic Dorset culture. Rather than trying to explain all the Norse artifacts found in the Dorset context as signs of "friendly contact" and noting that the Dorset "relished trade," why didn't she explore the possibility that the Dorset were in fact Norse or from a common, Arctic-exploring ancestor? After all, the Norse are indisputably the most successful and capable Arctic explorers known. They didn't suddenly gain these skills in the 800s A.D.

KARL HOENKE
Kelseyville, California

According to archaeologist Max Friesen, who specializes in the region, ancient DNA from the Dorset people is distinct from Norse DNA, so there's no shared ancestry.

Corrections

NOVEMBER 2012, CHEETAHS ON THE EDGE
Poster: The speed noted for cheetah Tommy T should've been approximately 45 feet per second, not 100 feet per second.

FEEDBACK

Readers offered their theories on why the Dorset people disappeared from North America.



"I think it likely that the rats brought bubonic plague to the New World on Norse ships; the 14th century was the time of the Black Death in Europe."

"Could it be the prolonged contact with the Vikings that led to the Dorset's disappearance?"

"The introduction of illnesses ... could have wiped them out."

"Might the Dorset simply have ... merged with surrounding local cultures?"



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Sarah Parcak
National Geographic
Emerging Explorer

EXPERTISE
Egyptologist

LOCATION
*South Sinai
Peninsula, Egypt*

The Sting We were working on the west coast of the Sinai Peninsula, where ancient Egyptians once processed copper (important for their finery). They smelted it in little pits, and we were trolling for evidence—ash, bits of copper slag—in foot-and-a-half-wide holes.

Scorpions like holes. We had to put our arms in the holes to dig out the smelting residues. We always performed critter checks before an excavation, but one morning I put an arm in and felt a sharp pierce. When I brought my hand out, it was red and already swelling. Here yellow-colored scorpions' stings mean more or less instant death; about eight other local scorpion species' stings are somewhat less lethal but excruciatingly painful. I'd just been stung, and there was no way to tell by what. I knew I had to keep my heart rate low so that any injected poison wouldn't course through my blood. I tried staying calm.

Our Bedouin site monitor had an interesting way to treat bites: He coughed up phlegm, spit it on my arm, and rubbed it in. Then he took out a lighter to cauterize the wound. I stopped him just in time. Then the ambulance arrived. When I told the driver I needed to go to the hospital, he started in on a love poem to me instead. At the hospital the doctor looked disdainfully at my wrist and said, "It is nothing." After I persuaded him to hook me up to a precautionary IV, a nurse brought some antivenom. I rolled up my sleeve, but she pointed to my bottom and said, "This is where shots go in Egypt."

The IV's morphine left me limp. When our site inspector heard I'd possibly been stung by a scorpion, he rushed to the hospital. Finding me motionless, he thought I'd died. I hadn't, obviously. But I still don't know what got me—I never saw it coming in that sandy pit.



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VISIONS

An underwater photograph showing several swimmers in dark wetsuits swimming through clear blue water. They are surrounded by a large school of fish, likely mackerel, which are scattered throughout the scene. The lighting is bright, creating a clear view of the swimmers and the fish. A small yellow horizontal bar is located below the word 'VISIONS'.

United States

Startled fish scatter as Ironman athletes begin the triathlon's first leg off the coast of Hawaii's Big Island. Competitors have up to 17 hours to finish the race: a 2.4-mile open-water swim, followed by 112 miles of bicycling and a 26.2-mile run.

PHOTO: DONALD MIRALLE





England

Just four days old and 2.5 inches long, an abandoned hoglet—as baby hedgehogs are often called—snuggles up to a folded towel at a rescue center in Royal Tunbridge Wells, Kent. Warmth and cleanliness are vital to keeping the tiny animals healthy.

PHOTO: PHIL YEOMANS, BOURNEMOUTH NEWS AND PICTURE SERVICE



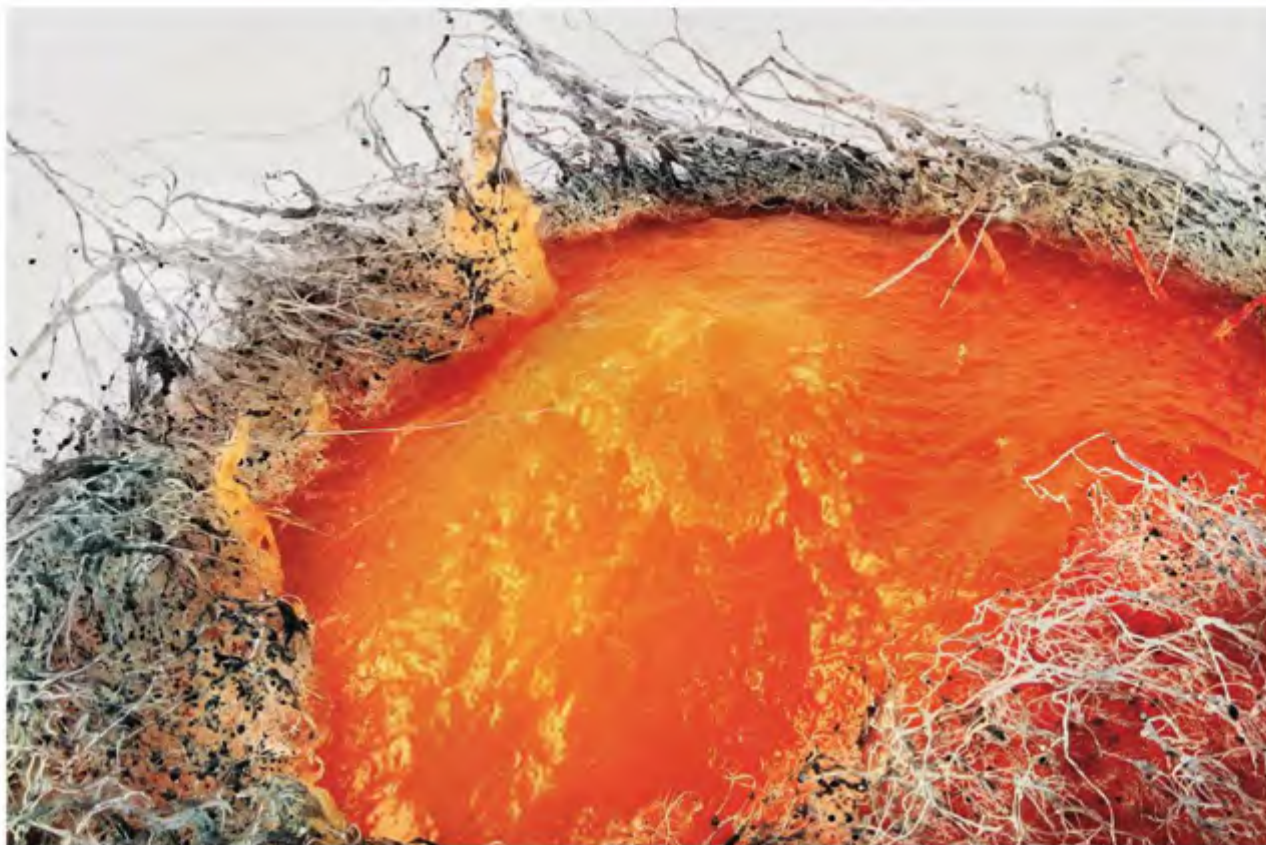




Israel

At an ultra-Orthodox Jewish wedding near Tel Aviv, Viznitz Hasidim gather around the chief rabbi (center, in white) and the groom (center, left). Men and women stay on separate sides of the wedding hall during the ten-hour ceremony.

PHOTO: ODED BALILTY, AP IMAGES



EDITORS' CHOICE **Harry Colquhoun** Edmonton, Canada

After taking macro photos of other edibles—nuts, berries, candy—Colquhoun, a software developer, was drawn to the colors of this moldy peach skin. "I'll have a pretty good catalog of moldy stuff in a year or two," he jokes. The photo is a composite of 30 highly focused images.



READERS' CHOICE

Gerson de Oliveira
São Leopoldo, Brazil

With only a round-trip train ticket and his camera, de Oliveira traveled to a nearby festival marking the anniversary of Brazil's 1835 Farroupilha Revolution. As part of the celebration, he says, "the rooster is a historical symbol and is considered a king."

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natgeotv.com/exploration

NEXT

SKYCAST

*Overhead this month
in parts of the world*

March 14
Eta Virginids
meteor shower



Easier Being Green

Some katydids might be mutants. Discovered in the 1770s, the oblong-winged species may have undergone a genetic change. Although their ancestors apparently were green, a fraction have been found with bright colors, including yellow, orange, and hot pink.

Geneticists aren't sure what caused the mutation. Entomologists have long thought the colors are symptoms of erythrism, an anomaly similar to albinism. Scientists working with a related species at Osaka Prefecture University pointed to

genetics over environmental factors as the cause.

Last summer mating trials for the oblong-winged katydid (above) at New Orleans' Audubon Insectarium followed up on an early 1900s study. The modern entomology team posited green as a recessive trait—good camouflage just makes them fittest for survival. Yellow and orange ones are second best, since these colors aren't revealed until the final molt. Pink ones are least likely to survive because they are that color from birth. Pink is actually their dominant trait but makes them easy prey when young. —Daniel Stone

**MEDICINE'S
MIRACULOUS
EXPLORERS**

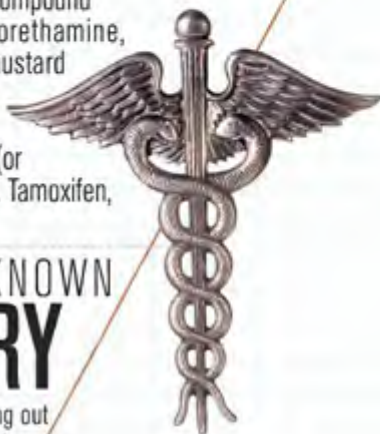
Move over, St. Polycarp, make room for St. Anesthesia and St. Antiseptic. Medical discoveries have so changed our lives that Winston Churchill felt we should have feast days to honor them. In that spirit, this quiz honors miracle workers on medicine's frontiers.

1. WHOSE PIONEERING WORK WITH ANTISEPTIC PROCEDURES MADE HIM THE "SAVIOR OF MOTHERS"?

- A. William Hunter, 18th-century "physician extraordinary" to Britain's Queen Charlotte B. Joseph Lister, surgeon and namesake of Listerine C. Louis Pasteur, namesake of pasteurized milk D. Hungarian grocer's son Ignaz Semmelweis

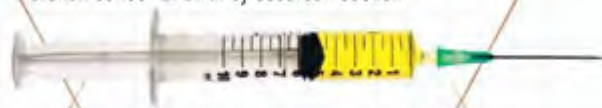
2. WHAT WAS THE FIRST SUCCESSFUL CHEMOTHERAPY DRUG?

- A. Salvarsan, an arsenic compound B. Mechlorethamine, cousin to mustard gas C. Vincristine, from the Madagascar (or rosy) periwinkle D. Tamoxifen, for breast cancer



3. WHAT IS THE EARLIEST KNOWN HUMAN SURGERY

- IN THE ARCHAEOLOGICAL RECORD? A. Cutting out an enemy's heart B. Prehistoric skull surgery C. Fixing broken bones D. Birth by cesarean section



4. IN 1796 EDWARD JENNER PIONEERED THE USE OF VACCINATION TO PREVENT DISEASE, LEADING TO THE ERADICATION OF SMALLPOX IN WHAT YEAR?

- A. Britain's Colonial Medical Service completed eradication in 1895. B. U.S. Army M.D. Walter Reed treated the last case in 1900. C. Napoleon made vaccination mandatory, leading to eradication in 1810. D. The last naturally occurring case was in Somalia in 1977.

5. IN 1940, AS THE BATTLE OF BRITAIN RAGED OVERHEAD, OXFORD UNIVERSITY RESEARCHERS SCRAMBLED TO SAVE WHAT MEDICAL DISCOVERY?

- A. A prototype polio vaccine B. A new heart medicine that would soon save Churchill's life C. The antibiotic penicillin D. A tuberculosis cure



6. WHO PERFORMED THE FIRST BREAST CANCER SURGERY USING GENERAL ANESTHESIA?

- A. Johns Hopkins surgical pioneer William Stewart Halsted B. Hanaoka Seishu, in Edo period Japan C. John H. Gibbon, Jr., inventor of the heart-lung machine D. Swiss-born 16th-century physician and chemist Paracelsus.

FIND ANSWERS ON PAGE 27.



GIFTS OF REAL ESTATE: Give a Home. Give Hope.

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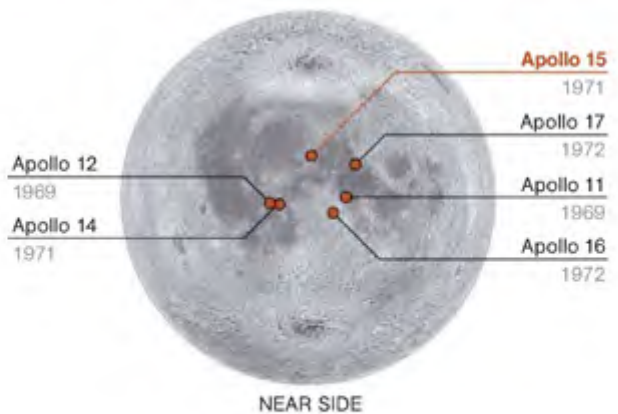
NEXT



NASA's exploration guidelines may help preserve lunar history.



Visit all six Apollo sites on our digital editions.





PROTECTING MOON SITES | Six Apollo missions put men on the moon. Among the things astronauts left behind are rover tracks (from Apollo 15, above), footprints, and still-in-use laser reflectors that tell scientists how far the Earth is from the moon. All are susceptible to damage from future explorers.

NASA is sharing suggestions for preserving the moon's historic places since official protection as World Heritage sites isn't an option. UNESCO hasn't had a say over celestial bodies, and the

1967 Outer Space Treaty states that no country can claim the moon, so it can't even be nominated.

The advice builds on lessons the U.S. space program learned the hard way. For example, don't land within 1.2 miles of site edges, to avoid sweeping the site with abrasive moon dust. Leaving the moon can cause problems too. Flags from five of the Apollo missions are still standing, all except for Apollo 11's—it was planted too close to liftoff and toppled from engine exhaust. —*Johnna Rizzo*



Food Fight Baboons started swiping food from people in South Africa's Cape Peninsula in the 1950s. They've been getting bolder. Of the 16 chacma baboon groups in the area, only one sticks to wild foraging. The others prefer food from houses, cars, and garbage cans. Raiding baboons open doors, yank out windows, and remove roof tiles, says the Baboon Research Unit's Justin O'Riain.

Rangers are monitoring the gangs, using paintball guns to keep the animals in wild spaces. Contact between baboons and humans can harm both—baboons scratch and bite, and humans sometimes kill the animals—and may spread disease. For both their sakes, O'Riain says, "baboons and people should not share space." —*Katia Andreassi*

A chacma baboon, one of a population of about 475 near Cape Town, snatches rhubarb from a shopper.



Planetary Gem Looks like there's a diamond in the sky—possibly the equivalent of three Earth masses. Yale astrophysicist Nikku Madhusudhan reports that a planet about 40 light-years away likely has a diamond layer nearly 2,500 miles thick, topped by a graphite surface. Called 55 Cancri e, the carbon-rich orb has little water and is fiery hot, at around 3,900 degrees Fahrenheit. "Scientists often assume that rocky planets are oxygen rich, like Earth," says Madhusudhan, who analyzed the planet's measurements. "This shows what extreme diversity can be out there." —*Luna Shyr*

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To merchants who have accepted Visa and MasterCard at any time since January 1, 2004: Notice of a 6+ billion dollar class action settlement.

Si desea leer este aviso en español, llámenos o visite nuestro sitio web.

Notice of a class action settlement authorized by the U.S. District Court, Eastern District of New York.

This notice is authorized by the Court to inform you about an agreement to settle a class action lawsuit that may affect you. The lawsuit claims that Visa and MasterCard, separately, and together with banks, violated antitrust laws and caused merchants to pay excessive fees for accepting Visa and MasterCard credit and debit cards, including by:

- Agreeing to set, apply, and enforce rules about merchant fees (called *default interchange fees*);
- Limiting what merchants could do to encourage their customers to use other forms of payment through, for example, charging customers an extra fee or offering discounts; and
- Continuing that conduct after Visa and MasterCard changed their corporate structures.

The defendants say they have done nothing wrong. They say that their business practices are legal and the result of competition, and have benefitted merchants and consumers. The Court has not decided who is right because the parties agreed to a settlement. On November 27, 2012, the Court gave preliminary approval to this settlement.

THE SETTLEMENT

Under the settlement, Visa, MasterCard, and the bank defendants have agreed to make payments to two settlement funds:

- The first is a "Cash Fund" – a \$6.05 billion fund that will pay valid claims of merchants that accepted Visa or MasterCard credit or debit cards at any time between January 1, 2004 and November 28, 2012.
- The second is an "Interchange Fund" – estimated to be approximately \$1.2 billion – that will be based on a portion of the interchange fees attributable to certain merchants that accept Visa

or MasterCard credit cards for an eight-month "Interchange Period."

Additionally, the settlement changes some of the Visa and MasterCard rules applicable to merchants who accept their cards.

This settlement creates two classes:

- A *Cash Settlement Class* (Rule 23(b)(3) Settlement Class), which includes all persons, businesses, and other entities that accepted any Visa or MasterCard cards in the U.S. at any time from January 1, 2004 to November 28, 2012, and
- A *Rule Changes Settlement Class* (Rule 23(b)(2) Settlement Class), which includes all persons, businesses, and entities that as of November 28, 2012 or in the future accept any Visa or MasterCard cards in the U.S.

WHAT MERCHANTS WILL GET FROM THE SETTLEMENT

Every merchant in the Cash Settlement Class that files a valid claim will get money from the \$6.05 billion Cash Fund, subject to a deduction (not to exceed 25% of the fund) to account for merchants who exclude themselves from the Cash Settlement Class. The value of each claim, where possible, will be based on the actual or estimated interchange fees attributable to the merchant's MasterCard and Visa payment card transactions from January 1, 2004 to November 28, 2012. Payments to merchants who file valid claims for a portion of the Cash Fund will be based on:

- The money available to pay all claims,
- The total dollar value of all valid claims filed,
- The deduction described above not to exceed 25% of the Cash Settlement Fund, and
- The cost of settlement administration and notice, money awarded to the class representatives, and attorneys'

fees and expenses all as approved by the Court.

In addition, merchants in the Cash Settlement Class that accept Visa and MasterCard during the eight-month Interchange Period and file a valid claim will get money from the separate Interchange Fund, estimated to be approximately \$1.2 billion. The value of each claim, where possible, will be based on an estimate of one-tenth of 1% of the merchant's Visa and MasterCard credit card dollar sales volume during that period. Payments to merchants who file valid claims for a portion of the Interchange Fund will be based on:

- The money available to pay all claims,
- The total dollar value of all valid claims filed, and
- The cost of settlement administration and notice, and any attorneys' fees and expenses that may be approved by the Court.

Attorneys' fees and expenses and money awarded to the class representatives: For work done through final approval of the settlement by the district court, Class Counsel will ask the Court for attorneys' fees in an amount that is a reasonable proportion of the Cash Settlement Fund, not to exceed 11.5% of the Cash Settlement Fund of \$6.05 billion and 11.5% of the Interchange Fund estimated to be \$1.2 billion to compensate all of the lawyers and their law firms that have worked on the class case. For additional work to administer the settlement, distribute both funds, and through any appeals, Class Counsel may seek reimbursement at their normal hourly rates, not to exceed an additional 1% of the Cash Settlement Fund of \$6.05 billion and an additional 1% of the Interchange Fund estimated to be \$1.2 billion. Class Counsel will also request reimbursement of their expenses (not including the administrative costs of settlement or notice), not to exceed \$40 million

and up to \$200,000 per Class Plaintiff in service awards for their efforts on behalf of the classes.

HOW TO ASK FOR PAYMENT

To receive payment, merchants must fill out a claim form. If the Court finally approves the settlement, and you do not exclude yourself from the Cash Settlement Class, you will receive a claim form in the mail or by email. Or you may ask for one at: www.PaymentCardSettlement.com, or call: 1-800-625-6440.

OTHER BENEFITS FOR MERCHANTS

Merchants will benefit from changes to certain MasterCard and Visa rules, which will allow merchants to, among other things:

- Charge customers an extra fee if they pay with Visa or MasterCard credit cards,
- Offer discounts to customers who do not pay with Visa or MasterCard credit or debit cards, and
- Form buying groups that meet certain criteria to negotiate with Visa and MasterCard.

Merchants that operate multiple businesses under different trade names or banners will also be able to accept Visa or MasterCard at fewer than all of the merchant's trade names and banners.

LEGAL RIGHTS AND OPTIONS

Merchants who are included in this lawsuit have the legal rights and options explained below. You may:

- **File a claim to ask for payment.** You will receive a claim form in the mail or email or file online at: www.PaymentCardSettlement.com.
- **Exclude yourself** from the Cash Settlement Class (Rule 23(b)(3) Settlement Class). If you exclude yourself, you can sue the Defendants for damages based on alleged conduct occurring on or before November 27, 2012 on your own at your own expense, if you want to. If you exclude yourself, you will not get any money from this settlement. If you are a merchant and wish to exclude yourself, you must make a written request, place it in an envelope,

and mail it with postage prepaid and postmarked no later than **May 28, 2013** to Class Administrator, Payment Card Interchange Fee Settlement, P.O. Box 2530, Portland, OR 97208-2530. The written request must be signed by a person authorized to do so and provide all of the following information: (1) the words "In re Payment Card Interchange Fee and Merchant Discount Antitrust Litigation," (2) your full name, address, telephone number, and taxpayer identification number, (3) the merchant that wishes to be excluded from the Cash Settlement Class (Rule 23(b)(3) Settlement Class), and what position or authority you have to exclude the merchant, and (4) the business names, brand names, and addresses of any stores or sales locations whose sales the merchant desires to be excluded.

Note: You cannot be excluded from the Rule Changes Settlement Class (Rule 23(b)(2) Settlement Class).

- **Object to the settlement.** The deadline to object is: **May 28, 2013**. To learn how to object, see: www.PaymentCardSettlement.com or call 1-800-625-6440. Note: If you exclude yourself from the Cash Settlement Class you cannot object to the terms of that portion of the settlement.

For more information about these rights and options, visit: www.PaymentCardSettlement.com.

IF THE COURT APPROVES THE FINAL SETTLEMENT

Members of the Rule Changes Settlement Class are bound by the terms of this settlement. Members of the Cash Settlement Class, who do not exclude themselves by the deadline, are bound by the terms of this settlement whether or not they file a claim for payment. Members of both classes release all claims against all released parties listed in the Settlement Agreement. The settlement will resolve and release any claims by merchants against Visa, MasterCard or other defendants that were or could have been alleged in the lawsuit, including any claims based on interchange or other fees,

no-surcharge rules, no-discounting rules, honor-all-cards rules and other rules. The settlement will also resolve any merchant claims based upon the future effect of any Visa or MasterCard rules, as of November 27, 2012 and not to be modified pursuant to the settlement, the modified rules provided for in the settlement, or any other rules substantially similar to any such rules. The releases will not bar claims involving certain specified standard commercial disputes arising in the ordinary course of business.

For more information on the release, see the settlement agreement at: www.PaymentCardSettlement.com.

THE COURT HEARING ABOUT THIS SETTLEMENT

On September 12, 2013, there will be a Court hearing to decide whether to approve the proposed settlement, class counsels' requests for attorneys' fees and expenses, and awards for the class representatives. The hearing will take place at:

United States District Court for the Eastern District of New York
225 Cadman Plaza
Brooklyn, NY 11201

You do not have to go to the court hearing or hire an attorney. But you can if you want to, at your own cost. The Court has appointed the law firms of Robins, Kaplan, Miller & Ciresi LLP, Berger & Montague, PC, and Robbins Geller Rudman & Dowd LLP to represent the Class ("Class Counsel").

QUESTIONS?

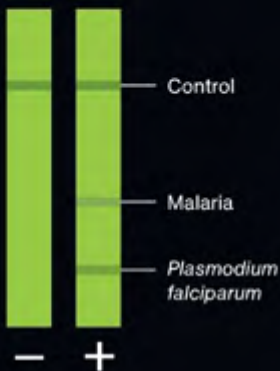
For more information about this case (*In re Payment Card Interchange Fee and Merchant Discount Antitrust Litigation*, MDL 1720), you may:

Call toll-free: 1-800-625-6440
Visit: www.PaymentCardSettlement.com
Write to the Class Administrator:
Payment Card Interchange Fee Settlement
P.O. Box 2530
Portland, OR 97208-2530
Email: info@PaymentCardSettlement.com

Please check www.PaymentCardSettlement.com for any updates relating to the settlement or the settlement approval process.

The Power of Mobile

Handheld devices aren't just for catching up on email. As Web connectivity and mobile technology expand, these gadgets are changing the way the world works. They pay for parking, advise farmers on how to price crops, and translate foreign languages. The best adaptations marry convenience and social good. One new system can turn a smart phone into a medical device, allowing patient screening in remote areas. A mere two ounces, the attachment and app digitize and enlarge diagnostic test strips, then analyze them for diseases like AIDS, tuberculosis, and malaria, says UCLA engineer and research leader Aydogan Ozcan. —John Briley



Reading the Results of a Malaria Test

A digital readout of a rapid diagnostic test (RDT) shows whether malaria is present. The disease's deadliest form has its own indicator (bottom). Results are uploaded to a database that helps track epidemics.



The Invention of the Year is Great News for your Ears

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New Personal Sound Amplification Product is an affordable way to "turn up the volume!"

Even the best inventions can get better. Cordless phones have gotten smaller and feature better sound... televisions have gotten sharper and more affordable. Now, the Personal Sound Amplification Product (PSAP) that has enabled countless people to "turn up the volume" is better than ever.

a renowned hearing institute, there is Perfect Choice HD. It's a PSAP designed to accurately amplify sounds and deliver them to your ear. Because we've developed an efficient production process, we can make a great product at an affordable price. The unit has been designed to have an easily accessible battery,



Now we've made Perfect Choice HD better than ever!

	Original Design	New Perfect Choice HD
Sound Quality	Good	Better – It Reduces Feedback
Volume	up to 30dB	35dB – 15% Louder
Hearing Tubes	One	3 to choose from for different situations
Ear Buds	One	2 to choose from for better fit and sound
One-on-One set up instructions	No	Yes – if needed

Perfect Choice HD is NOT a hearing aid. Hearing aids can only be sold by an audiologist or a licensed hearing instrument specialist following hearing tests and fitting appointments. Once they have you tested and fitted, you could pay as much as \$5000 for the product.

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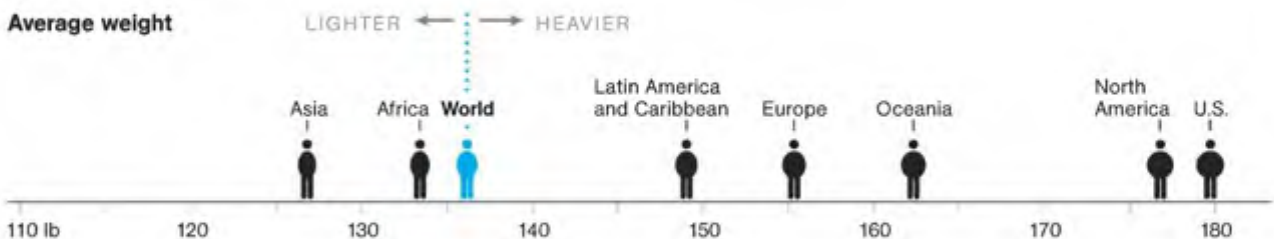
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Wandering Eyes Flatfish such as flounder and halibut look like regular fish when they hatch. Then it takes about two weeks for one eye to drift over the head to the other side. The anatomy is so peculiar, critics of Charles Darwin once argued that flatfish couldn't have evolved gradually because an intermediate fish—semiflat, with a partially migrated eye—would be maladaptive. One biologist advocated that modern flatfish arose instead from a sudden anatomical change. Until 2008 no fossils showing an evolutionary transition from symmetric to asymmetric fish had

been identified. Then paleobiologist Matt Friedman came across records of a 50-million-year-old fossil with one eye socket shifted upward but not migrated fully to the other side. When he studied the fossil along with a similar one (above) that he spotted in a Vienna museum, he found a “smoking gun”: the first evidence of an intermediate flatfish. Friedman, who last year published more detailed research on his initial study, hopes the discovery encourages a greater focus on fish fossils. As he notes, “They can illuminate how weird specializations arise.” —Luna Shyr

Weight of the World At seven billion plus, the global population isn't the only thing expanding; our waistlines are too. A team of U.K. scientists calculated that the people of Earth are now 3.9 million tons overweight. Russia and Egypt are among the top contributors. So is Mexico, which represents just a sliver of the world population. Who's carrying around the most excess fat? Americans. Indeed, if all countries mimicked the U.S., the collective hike in worldwide heft would equal the weight of another billion people. —Catherine Zuckerman



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If You Were an AOL Member Between March 1, 2006 and May 31, 2006, You May Be Eligible for a Payment from a Class Action Lawsuit

What is the lawsuit about?

In 2006, AOL made files containing some users' search queries available on the Internet. AOL said that the data was anonymous. The lawsuit claims, however, that: 1) some users' identities could be determined from the data, and 2) that AOL violated certain privacy and consumer protection laws by making it available on the Internet. AOL denies that it did anything wrong, and the Settlement does not prove otherwise. Both sides have agreed to settle to avoid the costs and risks of trial. A Court has not decided which side is right.

Am I included?

You are a Class Member if: 1) You lived in the U.S. or its territories at any time between March and May of 2006, and 2) Your search query data was available for download from research.aol.com in 2006. There is no way to determine based on your username alone whether your search data was included.

What does the Settlement provide?

The Settlement will provide up to \$5 million in payments to Class Members. AOL has taken certain steps to reduce the possibility of a similar data release. They will try to help Class Members who have been, or could be, identified by third-party websites that claim to host the search data by asking those sites to remove that data. AOL will also pay certain fees and expenses.

How much money could I get?

You may be eligible for a cash payment of at least \$50 from the Settlement. You will need to file a claim to get a payment.

Your actual payment amount may be less than \$50 depending on the number of valid claims received.

How do I get benefits?

The deadline for filing a claim has not yet been set, but you should file a claim as soon as possible because the claim deadline could be as early as **July 26, 2013**. Claim forms and details on how to file are available at www.AOLSearchDataSettlement.com or by calling 1-855-575-0127.

What are my options?

You do not have to do anything to remain in the Class, but you need to submit a Claim Form to receive a payment. Remaining in the Class will mean that you are bound by all orders of the Court and will not be able to sue AOL for the claims being resolved by the Settlement. If you want to sue AOL separately about the claims in this case, you must exclude yourself in writing by **May 3, 2013**. If you ask to be excluded, you cannot get a payment from this Settlement. If you stay in the Settlement, you may object to it in writing by **May 3, 2013**.

The Court will hold a hearing on **May 17, 2013** to consider whether to approve the Settlement, a request for attorneys' fees and expenses of up to \$1.5 million (the amount of which AOL reserves the right to contest), and a payment of \$9,900 for the Class Representative who helped the lawyers on behalf of the whole Class. If you wish, you or your own lawyer may ask to appear or speak at the hearing at your own expense.

For more information: 1-855-575-0127 www.AOLSearchDataSettlement.com

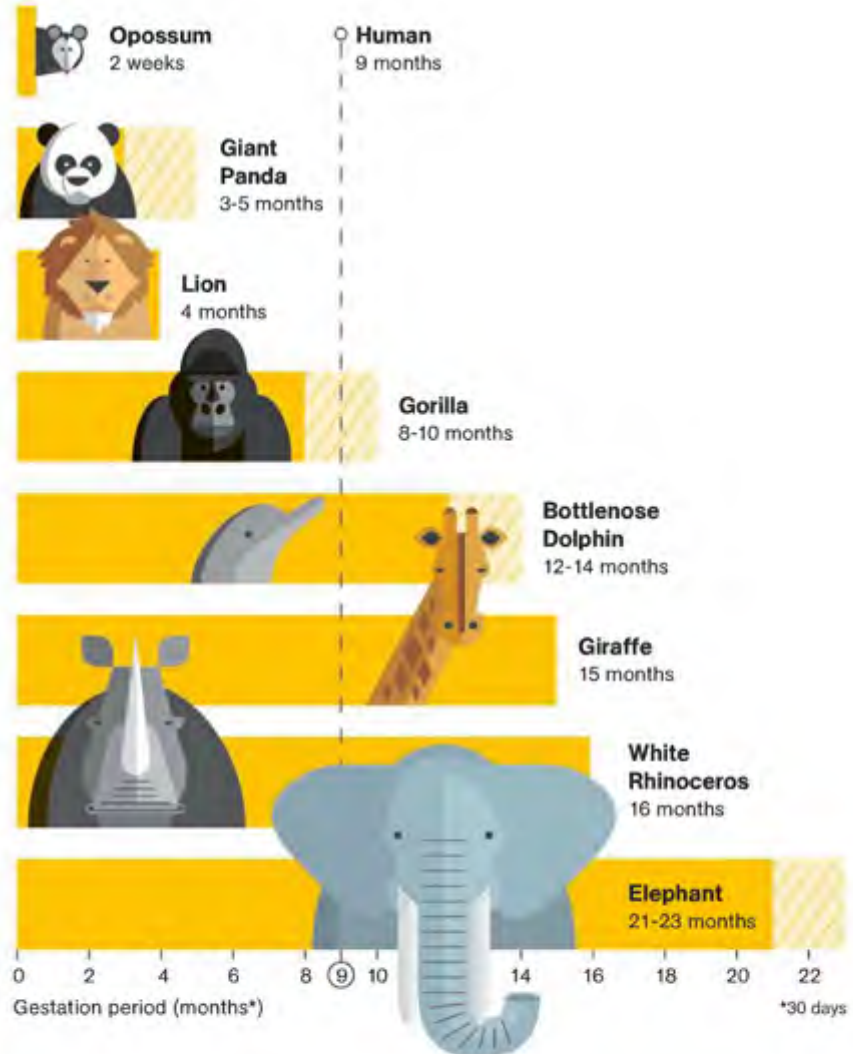


Waiting for Baby

An elephant's pregnancy lasts the longest of any mammal's—from 620 to 680 days, or close to two years. New research suggests how the pachyderms sustain this marathon gestation, which allows for more complex brain development and larger body size.

Elephants have multiple glands that form temporarily to help maintain pregnancy by secreting the hormone progesterone. Mammal mothers normally have one gland, called the corpus luteum (CL), for each embryo. Not so with elephants. They can have up to 42 CLs for a single fetus, says Imke Lueders, the study's lead author. This ensures a steady supply of the critical hormone.

The findings could aid breeding in captivity, where an elephant's birth is often greeted with excited trumpeting from the herd. —Luna Shyr



ANSWERS FOR EXPLORERS QUIZ

- (D) So many mothers in his Viennese clinic were dying of childbed fever, a form of sepsis, that obstetrician Ignaz Semmelweis wondered if doctors themselves were spreading infection. In 1847 he instituted a policy of hand washing with an antiseptic, and the death rate plummeted. But this was before Pasteur's germ theory, so other doctors ridiculed Semmelweis, who died in a mental institution at age 47 of sepsis.
- (A) "Chemotherapy" originally referred to the idea of using a chemical agent to treat disease, and Salvarsan was the magic bullet devised by Paul Ehrlich and Sahachiro Hata in 1909 as the first practical remedy for syphilis. Chemotherapy came to apply to cancer therapy only after development of the first effective cancer drug, mechlorethamine, in the 1940s.
- (B) Evidence indicates that opening up the skull to relieve pressure on the brain was a widespread surgical practice dating back at least 8,500 years. Skulls from individuals who underwent the procedure often show healing, meaning the patient lived.
- (D) The World Health Organization began its smallpox eradication campaign in 1967 and achieved victory over the disease in 1977. That October in Merca, Somalia, a 23-year-old cook named Ali Maow Maalin became the last person ever to acquire the disease by natural means. Unlike many before him, he lived.
- (C) Penicillin. Pathologist Howard Florey and his colleagues at Oxford University were so concerned about a German invasion that they rubbed *Penicillium notatum* spores into the fabric of their clothing. That way, if they were forced to destroy their work and evacuate, they would at least have the raw material to start up again wherever they landed.
- (B) Hanaoka Seishu used both Western and traditional Chinese medicine. He devised his anesthesia from a mix of seven herbs, inspired by an early Chinese model. In 1804 he performed a partial mastectomy on an anesthetized patient, and his brand of painless surgery was soon in great demand. Anesthesia wouldn't become common in Western medicine for another half century.



Natural gas flared as waste is a new sight on the Dakota prairie, where fracking—a way of extracting hard-to-reach oil—and directional drilling have sparked a boom.

The fracking frenzy in North Dakota has boosted the U.S. fuel supply—but at what cost?

The New Oil Landscape







This pump sits on property belonging to Richard and Brenda Jorgenson's neighbors, but the well runs under their property. Like many ranchers, the Jorgensons own their land but not the mineral rights, so they had no say in the placement of the well. Three more wells will be drilled within view of their grandchildren's swings. "It's scary," Brenda says.



A row of mobile homes alongside an abandoned farm building in Watford City signals a reversal of fortune in a state that had steadily been losing population. Since 2010 tens of thousands of people—most refugees from the great recession—have flooded into the oil patch hoping to find work. Those who don't succeed risk ending up homeless and jobless.



When Susan Connell arrives at the first oil well of the day, she tosses her stylish black-rimmed glasses onto the dashboard of her 18-wheeler, climbs down from the cab,

and pulls the zipper on her fire-resistant coveralls up to her neck. It's early July, about 7 a.m. We're on the Fort Berthold Reservation, in western North Dakota. Connell, 39, the mother of two young girls and one of the few female big-rig drivers in the oil patch, is hauling water. Produced water, as it's officially known. The drivers call it dirty water. During the early days of pumping at a new well, oil is accompanied by fluids and other substances used during drilling, along with salt water, which is abundant above the subterranean layers of rock where the coveted sweet crude is found. Eventually the man-made additives diminish, leaving mostly salt water. Five of the three-story-high tanks in front of us contain oil; the sixth, everything else. That's what Connell is here to transfer to a waste-disposal well.

"Just don't pass out on me," Connell says, half in jest. We've scaled a steep stairway to a narrow steel catwalk 30 feet above the ground, but she's not referring to the height. She says that one of the first times she opened the hatch atop a dirty water tank, she was overcome by fumes. "I fell to my knees." No one had warned her about the dozens of chemicals in the water, including hydrogen sulfide, H_2S , its rotten-egg odor created by bacteria growing inside wells. In high enough concentrations it can be poisonous, even lethal.

Ironically, the gas poses the greatest risk when it deadens your sense of smell, another safety lesson Connell had to learn on her own. Eventually someone gave her an H_2S detector, which she



By Edwin Dobb
Photographs by Eugene Richards



Out of their oil-coated coveralls, rig workers (from left) Jerry Roberts, T. J. Hibley, and Wallace Barnett ham it up at the “man camp” where the Mississippi natives live, south of Watford City. Most oil workers are transient, but the mayor hopes more will settle down with their families. Paying bills back home, not relocation, is on the minds of these men.

clipped to her collar whenever she approached a well that had turned “sour” enough to be hazardous. Once she was pumping dirty water from her tanker truck when the detector sounded. She scrambled away, thinking she’d escaped harm. But hours later she felt stabbing pains in her stomach, the prelude to a weeklong bout of vomiting. Her next purchase was a gas mask.

Connell tells me to stand upwind, then gingerly lifts the hatch. No fumes. It’s what she expected, having often hauled water from this well, but, she says, you never know when a routine activity will be interrupted by a nasty surprise. She unwinds a measuring tape into the tank. For a moment, from the vantage of the catwalk, I’m granted a bird’s-eye view of the surrounding country. Just outside the coral-colored gravel of the well site are patches of flax and sunflowers, then sealike fields of wheat, alfalfa, and canola, and beyond them, heavily eroded badlands through which the Missouri River has cut a wide, sweeping bend. The understated glory of the northern plains.

But my pastoral interlude is cut short. Connell has descended the stairs and is removing a 20-foot hose—like a fire hose, only heavier—from the side of the truck. Though only five feet six inches tall and weighing just a hundred pounds, she moves quickly, leaning forward to get traction as she drags the thick hose along the ground. She attaches one end to the rear of the truck tank, the other to an outlet at the base

of the storage tank. She then pulls a long metal handle, opening the storage valve. If you don’t look closely, you might miss the brunette pigtailed that fall to Connell’s shoulders, the blue eyes in the shadow cast by her well-worn baseball cap.

A half hour later we’re back in the cab, a hundred barrels heavier, rolling away. Connell doesn’t use the clutch much. “Just like a pro,” she says with a mischievous smile, before admitting it took months to master shifting gears at stoplights.

Truck driving is the most common job in the oil patch, an area about the size of West Virginia where advances in drilling and extraction technology have made it possible to remove oil from deep, widely dispersed deposits. Since early 2006, production from what’s known as the Bakken formation has increased nearly 150-fold, to more than 660,000 barrels a day, moving North Dakota into second place among domestic suppliers, behind Texas and ahead of Alaska.

No one but a handful of industry insiders saw that coming. Now some optimistic oilmen predict that the state’s daily output could eventually close in on Texas’—at two million barrels. The number of wells could increase from the roughly 8,000 operating today to between 40,000 and 50,000. By the time the frenzy ends, perhaps 20 years from now, as many as 14 billion barrels of high-quality crude may have been removed. Until more pipelines are built in this landlocked rural region, most of the oil and water will be transported by truck. So will everything else needed for swift, large-scale development: gravel, construction materials, tools, machinery. The prairie is being industrialized. If the transformation needs an emblem, there’s no better candidate than Connell’s 18-wheeler.

Change of such scope and intensity is bound to raise questions. Thousands of people are converging on the area, looking for work, looking for redemption, looking for trouble. And jobs are plentiful. In Williston, in the heart of the oil patch, the unemployment rate is less than one percent. But how does a region of farms and small



Edwin Dobb covered a controversial mine in Alaska in December 2010. Eugene Richards portrayed the emptying of North Dakota in January 2008.

towns weather the human onslaught? Another risk is environmental damage. Most attention has focused on hydraulic fracturing, or fracking, by which large amounts of fresh water combined with sand and other substances, some toxic, are driven under high pressure down wells drilled into deep layers of shale, creating cracks through which bubbles of trapped oil and natural gas can escape into the well. Where will all the clean water come from? How will the dirty water that's pumped out be prevented from contaminating groundwater, as has happened in other parts of the country? Stepping back for a broader view, can the inestimable values of the prairie—silence, solitude, serenity—be preserved in the face of full-throttle, regionwide development, of extracting as much oil as possible as fast as possible?

The implications are already reverberating far beyond North Dakota. Bakken-like shale formations occur across the U.S., indeed, across the world. The extraction technology refined in the Bakken is in effect a skeleton key that can be used to open other fossil fuel treasure chests.

That technology, stunning enough in itself, coupled with shifts in the marketplace that favor exploiting deposits that are harder, and therefore more expensive, to tap has convinced some experts that the carbon-based economy can continue much longer than they'd imagined. Billionaire oilman and Bakken pioneer Harold Hamm argues that the assumption we're running out of oil and gas is false. America, in his view, needs a national policy based on abundance, one that doesn't favor developing renewable sources of energy. Either way, you're not likely to hear anyone in the oil patch mention what's ultimately at stake if we keep burning fossil fuels with abandon.

"Climate change?" Connell says. "We don't talk about that here."

North Dakota has boomed before, in the 1950s and '80s. But besides being much larger and likely to last much longer, the current boom differs from earlier ones because it has coincided with an economic malaise. For refugees from the recession, the Bakken is a

Can the inestimable values of the prairie—silence, solitude, serenity—be preserved in the face of full-throttle development, of extracting as much oil as possible as fast as possible?

chance—often the last chance—to escape ruin.

So it was for Susan Connell. While we head for the disposal site on a two-lane highway chewed up by truck traffic, she describes how she came to be behind the wheel of a Kenworth Anteater. The trouble started in 2009, when she and her husband could no longer find construction work in southwestern Montana, where they live. By the fall they were three months behind on their house payments. The bank sent threatening letters. Then Connell heard that truckers were needed in North Dakota. The Delaware native had driven a commercial bus between Philadelphia and Atlantic City, also an airport transit bus in Portland, Oregon. How much harder could an 18-wheeler be? But to qualify she would have to upgrade her license, and for that she would need to attend a special training program. Cost: \$4,000. At a time when Connell and her husband could scarcely buy groceries for their kids, they charged the fee to a credit card. "It was a big gamble," she says, referring less to the likely availability of work than to the reception she would almost certainly get in what she calls the "testosterone cloud."

When she was a teenager, Connell did stand-up comedy in cafés in Philadelphia. HBO and *Saturday Night Live* expressed interest, but her abiding love was art—painting, filmmaking, and especially writing stories (Continued on page 44)





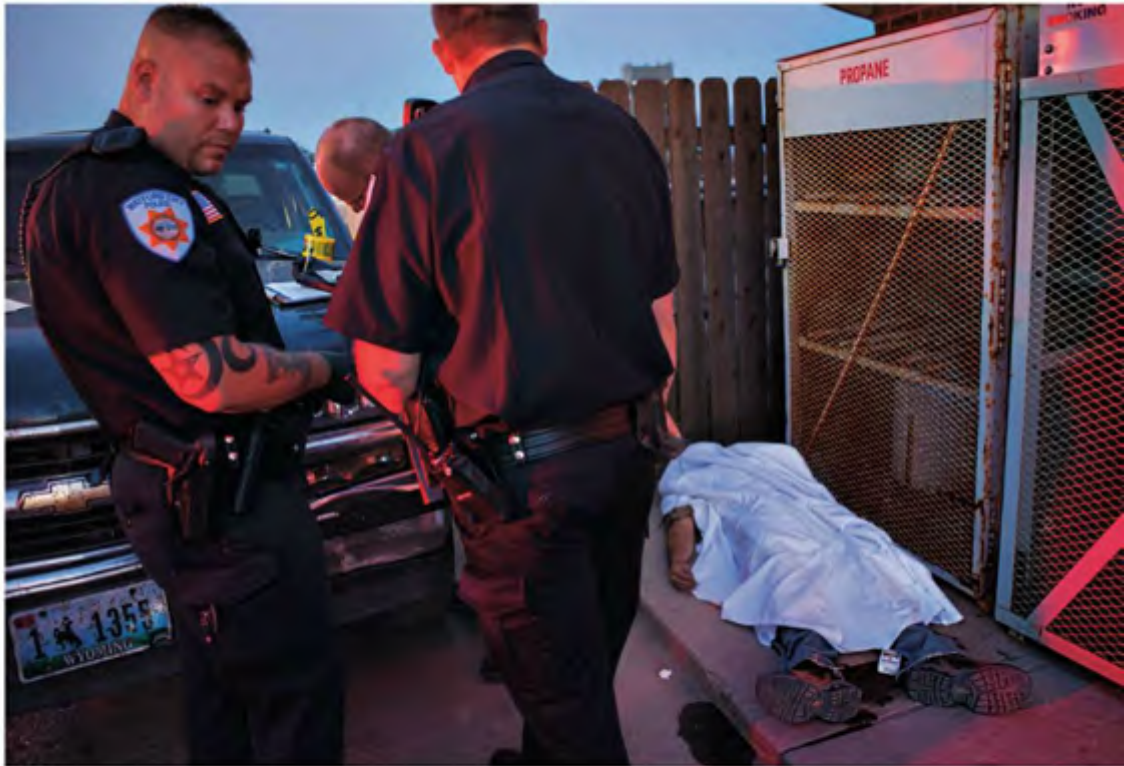
Near Epping, Arlin Fischer (hand on hip) oversees a workover rig, which allows the men to replace large drilling pipe with smaller, less expensive production pipe. Some 8,000 wells have been drilled in western North Dakota; there could eventually be 50,000.

Below: Roughnecks stand on a deck and remove two miles of heavy steel drilling pipe, one 32-foot section at a time, as oil and natural gas spew from the well. The hard, dangerous work on oil rigs pays up to \$120,000 a year.

Top right: Susan Connell, who calls herself a “badass trucker,” transfers salt water from her 18-wheeler to a waste-disposal tank on the site where the water will be injected into the ground. Unlike Connell, most women here work in service industries.

Bottom right: The Minnesota man under the sheet, who’d been suffering from pneumonia, collapsed and died outside a Watford City gas station. The population explosion has driven up medical emergencies and crime, overwhelming services.







A lined pit containing rainwater and borehole waste lies at the foot of Thunder Butte, sacred to area tribes. According to legend, the butte is the source of the world's rain. Fracking requires large amounts of fresh water; in this drought-prone region, drawdown and contamination of aquifers worry many.



"My town was dying," says Brent Sanford, mayor of Watford City, a community that's been transformed by the boom. "This is a full-scale mining operation, and I'm all for it. Now we can get back to work."

and acting them out, sometimes with props, before audiences. She was the lead singer in a rock band for six years. All that experience bred in her a cheerful, disarming fearlessness. Now she was auditioning for a demanding new role.

On a frigid day in mid-December, Connell fixed pancakes for her daughters, fought back tears as she said goodbye, then made the seven-hour trip from southwestern Montana to the Montana-North Dakota border. With the temperature dropping at night to well below zero, she alternated between sleeping in her car and staying in shabby motels while applying at more than a dozen trucking companies. All turned her down. Several managers said women didn't belong in the oil patch. One guy in Tioga told her it was a sacrilege that she wasn't home tending to her children. She was angry. "They were messing with my livelihood," she says.

When the first offer came, after the holidays, it was to haul grain, not water or oil, and for considerably less pay, over a territory covering most of western North Dakota as well as eastern Montana and southern Saskatchewan. To make matters worse, the winter of 2010-2011 was unusually severe. This was no place to be piloting an 18-wheeler for the first time—and alone. "I was so nervous I thought I was going to die," Connell says of her inaugural trip. Everywhere she drove, the roads were iced

over. "I chained up all the time," she says. After much trial and error, occasionally featuring a cursing farmer, she learned how to back up an 18-wheeler across snow-laden fields, then to unload silos while standing atop the trailer in 20-below weather, often in the dark, sleet and grain dust pelting her face. She did her own truck maintenance, including oiling hubs and greasing bearings.

During the first months of 2011, Connell continued to apply for oil jobs. The odds were improving because the need for semi operators was increasing rapidly. Since the 1990s fracking had been combined with directional drilling—excavating horizontally from the bottom of the vertical portion of a well into thin layers of oil- and gas-bearing rock. In the Bakken, Harold Hamm's Continental Resources and other nimble companies had refined that technology by extending the lateral leg as far as two miles and altering the fracking-solution recipe. In 2004 Continental had brought in the first commercially viable well in the state. Two years later an EOG Resources well produced oil under so much pressure that the company had to shut down the well until a second one could be drilled to reduce the pressure.

"That created huge excitement," recalls Lynn Helms, director of the North Dakota Department of Mineral Resources. Anticipation was building. The turning point came at the end of 2009, when Brigham Oil & Gas split the single lateral leg of a well south of Williston into 25 legs, each of which was fracked separately, making it possible to reach more oil—hundreds of barrels a day. Helms calculated that the first year of every new well, from drilling to fracking to early production, would entail 2,000 truck trips. This didn't include the hauling out of huge amounts of oil and salt water during the remainder of a well's life. State officials were already thinking in terms of tens of thousands of new wells, most of which would be located in only four counties bordering the Missouri River—Williams, Mountrail, McKenzie, and Dunn. The implications were staggering. "A flag went up," Helms says. Much more of

everything—manpower, highways, railroads, electricity lines, patience—would be needed.

This is a full-scale mining operation,” says Brent Sanford, mayor of Watford City, a McKenzie County community that’s been transformed by the boom. “And I’m all for it.” The 40-year-old, fourth-generation native sits in front of a computer monitor in his office at S & S Motors, which his grandfather started in 1946 and he took over when he moved back home nine years ago. While scanning for bargains on a car-auction website, he explains his enthusiasm. “My town was dying,” he says. Watford City was one of dozens facing the same plight, which once prompted geographers to propose that the region be turned over to the buffalo again, a notion you don’t want to bring up with Sanford or any of his neighbors unless you’re itching for a fight. Every year western North Dakota was becoming emptier—of promise as well as people. The fracking boom has reversed the decline. “Now we can get back to work,” Sanford says.

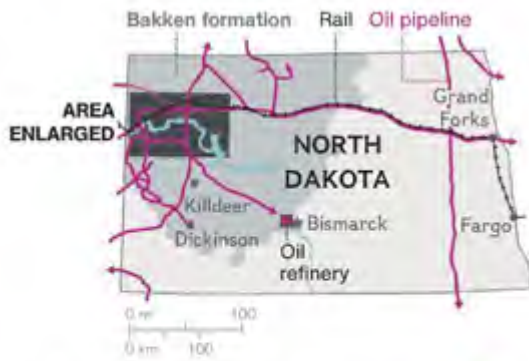
To appreciate the nature of the work, I visited a well northeast of Williston. A leak had developed at the bottom of the vertical leg, about two miles underground. To bring the pipe to the surface, a derricklike structure, similar to a drill rig but smaller, had been erected. On a deck about 30 feet up the rig, four roughnecks were removing the entire 10,750 feet of pipe, one 32-foot, 500-pound segment at a time, a task both tedious and highly dangerous. A device underneath the deck held each segment in place as it emerged, to prevent the pressure of the oil from sending all two miles of pipe, some 84 tons of steel, rocketing into the sky. As if to remind us of that possibility, a fountain of oil suddenly burst from the hole, covering the men, their hard hats, faces, everything. The odor of gas permeated the air. More fountains followed. Here were guys who knew what they were doing, who were exposed to constant peril, who were paid well, and who, because of all that, had ample reason to be proud. It was skilled manual labor in perilous

circumstances, which in our age of high-tech jockeys and private-equity sharks seemed exotic, almost heroic.

Sanford isn’t blind to the trauma Watford City is undergoing. A population that in the past two years has soared from about 1,700 to at least 6,000 and, Sanford estimates, perhaps as many as 10,000. A housing shortage so acute that men—and it’s still mostly men—are forced to sleep in their trucks or in overpriced motels; pay “gouge-zone” fees to park their campers, RVs, and house trailers; or live in one of the expensive prefab, dormlike “man camps” that serve as instant but sterile bedroom communities for towns and work sites. Streets clogged with noisy, exhaust-belching tanker trucks, gravel trucks, flatbeds, dump trucks, service trucks, and—the personal vehicle of choice in the oil patch—oversize, gas-gorging pickups. More crime, more highway accidents, more medical emergencies. People on fixed incomes forced to move because they can’t afford steep rent hikes. Overtaxed water and sewer systems. Prostitution. Registered sex offenders at large in the community.

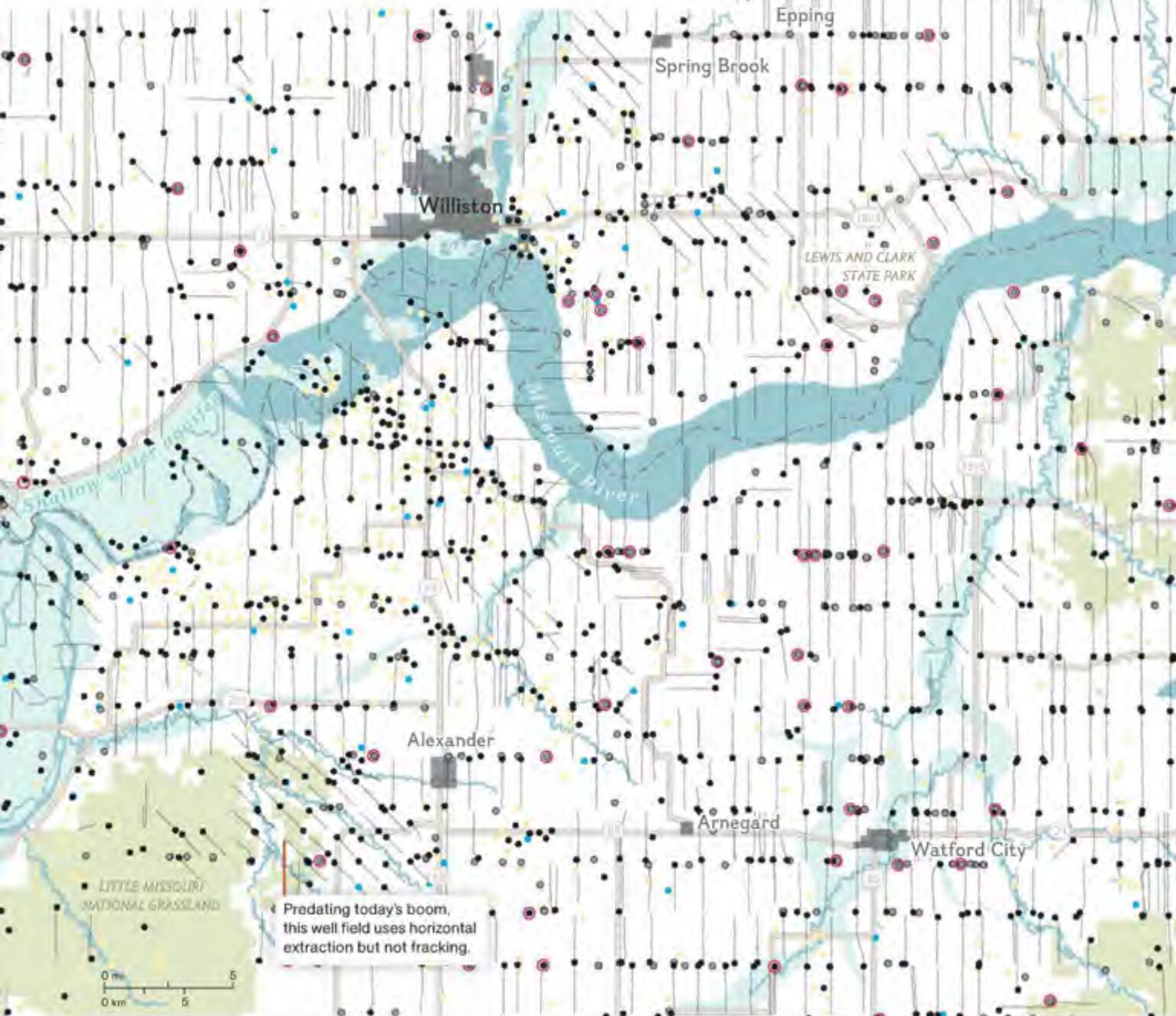
But Sanford, a former CPA, believes the media have overemphasized the negative side of the ledger. Not only will Watford City survive intact, he insists, but the eventual benefits will far outweigh the costs. Regarding housing, “our greatest problem,” he says the difficulties should be seen as part of an evolution from temporary lodging like RVs and man camps to “rooftops”—new apartment buildings and, eventually, single-family homes. Already the elementary school has been expanded. A new recreation center, a public housing and day-care complex, and a hospital will soon be built. Roads are being repaired, upgraded, widened. All across town old businesses—including S & S Motors—are flourishing, and new ones are opening their doors.

Trucking is one of the most lucrative enterprises. Seven years ago Power Fuels, a Watford City-based company that specializes in transporting oil, water, and other fluids, had a staff of 50. Today it has 1,200 employees in four different towns and is building eleven 42-unit apartment



PIPELINE SHORTAGE

Only a quarter of North Dakota's oil wells connect directly to pipelines. Most of the oil is trucked to pipelines or rail stations to be sent out of state. North Dakota's lone refinery can handle only a tenth of the current output.



Drilling the Prairie

If earth were transparent, you'd see this pattern on a flight over northwest North Dakota. From the more than 3,000 active wells shown here, pipes drop down nearly two miles, then dogleg horizontally for a mile or two through the layer of shale called the Bakken formation. Lines on this map show the horizontal pipes, where fracking for oil occurs.

WELLS

- Drilling rig
- Active oil well
- Status undisclosed
- Inactive, dry, or abandoned well
- Fracturing-fluid disposal well

TOP VIEW (shown in map)

- Wellhead
- Horizontal pipe, two miles deep

SIDE VIEW

- Ground level
- Horizontal pipe, two miles deep



1951: The state's first oil was extracted here, from layers below the Bakken.

Well featured on pages 48-49

2006: The fracking boom began with these wells.

1953: Natural fractures in this region allowed the first oil extraction from the Bakken.

1 NESSON ANTICLINE Early traditional drilling, in the 1950s, focused on this north-south strip, where reservoirs of oil are trapped along an arching geologic structure called an anticline.



2 SANISH FIELD Refinements in fracking technology let drillers in this field use longer horizontal pipes, reducing the number of oil platforms needed on the surface.

3 PARSHALL FIELD Shorter horizontal pipes mark this field. The first large-scale fracking of the Bakken formation began here, in 2006, spurring the ongoing boom.

Two-square-mile lease

One-square-mile lease

AQUIFER

NATIONAL GRASSLAND OR WILDLIFE REFUGE

1 DRILL

A well is drilled nearly two miles down, then curves at the bottom and runs into the Bakken formation. The Iverson well (right) used 350 pieces of pipe, weighing 87 tons.

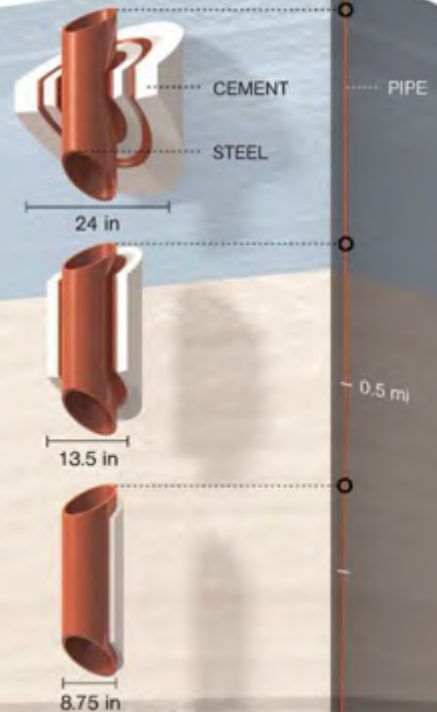


DISPOSAL WELL

Waste pools are prohibited in North Dakota. Trucks haul away waste fluid and pump it into deep wells.

2 PROTECT

Cement and steel casings are inserted to guard against seepage from the pipe into groundwater.



AIR QUALITY



LEAKY PONDS



FAULTY WELLS



SPIILLS

CAUSES FOR CONCERN?

The states, not the federal government, regulate fracking, so procedures differ across the country. Well locations, underlying geology, and whether oil or natural gas is the target also affect the procedures. Worries about fracking vary too. One main concern now is that gas leaks worsen air quality. The long-term consequences of fracking are unknown.

UPPER BAKKEN (SHALE)

MIDDLE BAKKEN (SANDSTONE)

LOWER BAKKEN (SHALE)

120 ft

THE BAKKEN FORMATION

In this oil-rich formation, the well descends through shale, then travels horizontally through sandstone.

The well is more than seven Empire State Buildings deep (1,454 feet each).

Fracking the Prairie

There are three basic steps in hydraulic fracturing, or fracking, the pumping of fluids at extreme pressure into rock deep beneath the Earth's surface to extract the embedded oil. The oil well depicted here is the Iverson 21-14H, in western North Dakota. It plunges 10,500 feet to frack sandstone and shale in layers of rock called the Bakken formation. The area produces some 660,000 barrels of oil daily, which has created a boom for the state but has also given rise to concerns about the environmental costs.

THIS WELL'S FRACTURING FLUID

80.5% WATER

19% PROPPANT

Proppant is a combination of natural quartz sand and man-made ceramics. It props open fractures in the rock so oil can flow more freely.

0.5% CHEMICALS

Additives, many toxic, are used to inhibit bacterial growth, minimize friction, and increase viscosity.

WHERE DOES THE USED FLUID GO?

80% DISPOSED OF

Most is pumped into injection wells at least 2,500 feet below potable water.

20% RECYCLED

PRODUCTS USED IN LIFE OF ONE WELL

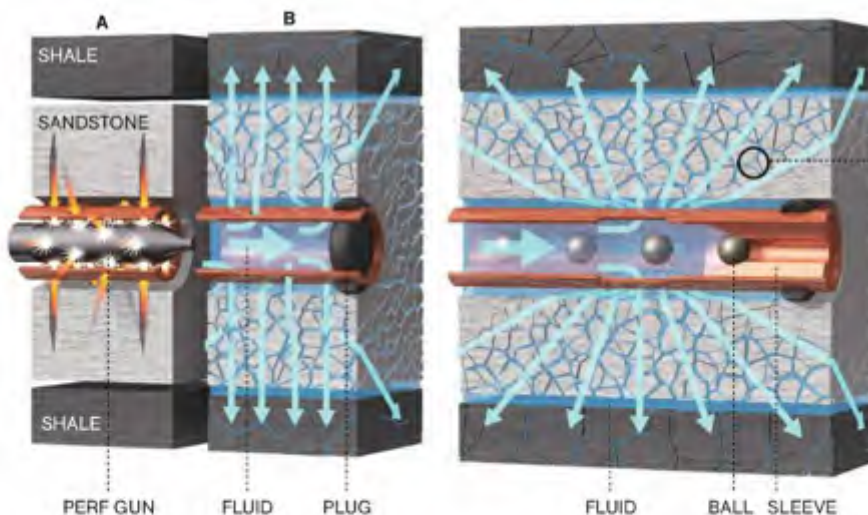
2 MILLION GALLONS OF WATER

4 MILLION POUNDS OF PROPPANT

350+ BARRELS OF CHEMICALS

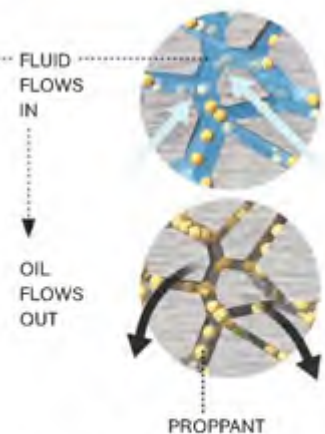
3 FRACTURE AND OIL FLOW

Fluid is pumped under high pressure down the well and into the rock to the end of the pipe, fracturing the rock in stages to release the oil. Two methods are used, with the sliding sleeve (below right) employed first.

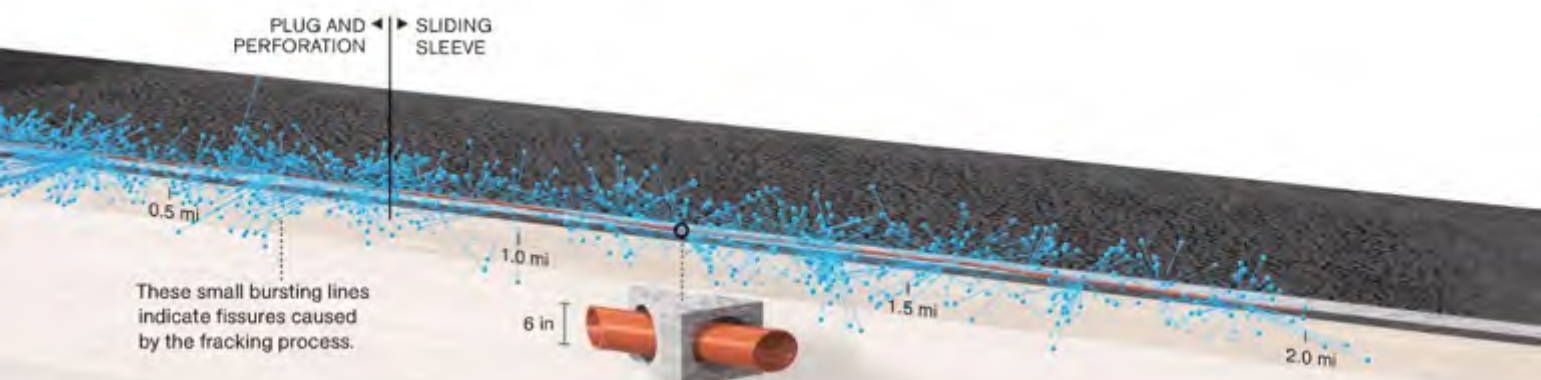


PLUG AND PERFORATION A plug blocks off a section of pipe, and a "perf gun" blasts small holes in the sandstone (A). Fluid is pumped in at high pressure (B), releasing the oil.

SLIDING SLEEVE Plastic balls are forced down the pipe, pushing open sliding sleeves to expose holes in the pipe. Fluid shoots out through the holes, fracturing the rock.



Fracking fluid expands cracks in the rock, releasing oil, which flows back up the well.



complexes to house them. An 18-wheeler tank truck can bring in \$40,000 a month—if everything goes right.

One night in early April 2011, waiting out the “umpteenth blizzard” of the season with two dozen oil and water drivers at a Cenex gas station in Parshall, Connell insinuated herself into conversations, inquiring about jobs and collecting phone numbers of trucking firms. Someone asked her where her rig had slid into the ditch. Turns out that Connell, the only female driver in the room, was also the only driver who hadn’t gone off the road during the storm.

The following day, she got up at 5 a.m., shoveled out her snowbound 18-wheeler, and was the first of the stranded drivers back on the road. That didn’t escape the notice of her newfound admirers, including one of the guys Connell had talked to the night before—the owner of a small water-hauling company based in Killdeer, who had one truck and wanted someone to help him drive. Soon afterward he called and offered her a job. Her pay jumped from \$600 a week to \$2,000. There would be no more worrisome letters from the bank. She’d saved the family house.

In western North Dakota stories like this are commonplace—among drivers, construction workers, and roughnecks; service providers and equipment suppliers; geologists, engineers, and drilling specialists. But viewed at close range, the apparent robustness of the Bakken boom sometimes looks like a collection of fragile mini-booms. Within six months of Connell’s lucky layover in Parshall, for instance, her new boss didn’t have enough work to keep her on.

Of everything that’s happening here today—of all the change and growth—what will last? Will the enduring things be the most desirable things? These questions haunt Dan Kalil, chairman of the Williams County Board of Commissioners. “Oil is a rental business,” he says, meaning that it doesn’t stay in one place, doesn’t owe any allegiance to the traditional farming and ranching way of life, which Kalil’s family has been doing west of Williston, the county seat, for more than a hundred years. Perhaps nothing better symbolizes the contrast than

the two most iconic structures on this part of the prairie—the itinerant drill rig and the steadfast grain silo. “When the industry goes south, and it will go south,” Kalil says, “they just walk away.”

Kalil doesn’t oppose development, only development that’s run amok, which is how he sees this boom. “Slow it down,” he urges, echoing a sentiment—a recurring, ever louder counterchorus—heard throughout the oil patch. Contain it before it destroys the closely bound communities and easygoing lifestyle that, during the best of times, have been the hallmarks of the region. Even if slowing things down were still possible—and Kalil has all but lost hope of that—the only effective way would be to limit the number of drill rigs or well permits, and state officials have no appetite for either.

“It breaks my heart,” Kalil says.

I put the blessing-or-curse question to Connell, who’s gone from boom to bust and back again several times, including finding steady work with a large trucking company based on the Fort Berthold Reservation when the Killdeer operator’s work slowed. Connell is on the last run of a 12-hour shift, and we’re back at the reservation well with the breathtaking view of the Missouri, loading more dirty water. “How could I be a part of this?” she says, referring to the drunken fights and homelessness, oil leaks and dirty-water spills. “I struggled. But I finally made my peace with it.” Behind us a gas flare, its ten-foot flame roaring upward, suddenly expands and becomes more violent, sounding like a blast furnace. There are few gathering pipelines in the Bakken, so at least a third of the natural gas that comes up with the crude is burned off, a waste all regret and the state hopes to end soon. At night in some areas the prairie is ablaze with giant candles, a sight both wondrous and unsettling. “During the winter,” Connell says wistfully, as if recalling a cherished childhood memory, “we’d park next to the flares to stay warm.”

She writes down the amount of water she’s removed from the storage tank: another hundred barrels. “There’s good and bad in everything,” she says, straining to articulate something that defies explanation. “I just accept it.” Which isn’t

to say she wouldn't rather move on. "I've been trying to leave," she says, explaining that the work is exhausting, unreliable, and lonely. The separations from her family have been getting more difficult for everyone; every time she leaves home, her daughters beg her not to go. And in the testosterone cloud, physical threats and attempts at sexual extortion have occurred often enough to convince her that she should never go anywhere without weapons. Brandishing a steel rod is usually all she needs to discourage those who menace her. But well-paid work is still in short supply back home, and, she says, that's not the only thing keeping her here. She's proved she can do the job, and do it better than many of her fellow drivers. Most important, she's made a place for herself in life. "After working hard all day," she says, "I start to feel feisty, like the guys." She chuckles, adding with a sly smile, "I'm a badass trucker."

The day I drove to the Jorgensons' place, in the northwest corner of Mountrail County, was the day I fell under the spell of the prairie. North of Tioga I turned off Route 40, heading east. On both sides of the gravel road, fields of wheat, alfalfa, and sunflowers spread to the horizon. In this part of the country, if you're not in a hurry, you can't help but notice the sound. There's so little of it, for one thing, and it's orchestrated mostly by the wind, howling, thrumming, or, as on that morning, whispering, as it sifted through the still-green crops. I continued for eight miles on a road without bends in a land without contours, none of which prepared me for my destination—the White Earth Valley, a wide, grassy basin whose subtle charm owes much to the flatness of the area surrounding it. Here, on a bluff above the valley, Richard and Brenda Jorgenson, both 59, have lived for more than 30 years.

While Richard drove a swather in a nearby field, cutting pungent alfalfa for cattle feed, Brenda gave me a tour on an ATV with two of her grandchildren, seven-year-old Ashley, sitting on her lap, and five-year-old daredevil Kyle,

The owner of a small water-hauling company, who had one truck and wanted someone to help him drive, offered Susan Connell a job. Her pay jumped from \$600 a week to \$2,000.

riding hands free next to me in the back. We headed north of the house, skirting patches of virgin prairie—home to coneflowers, blue-eyed grass, and blanket flowers—and coulees, where ash trees and Juneberry bushes were abundant.

Brenda was still in college when Richard first showed her the valley. "It was instant love," she says. Making a go of it, however, has never been easy. Eight years passed before they were able to build a house, which they did themselves, moving in on Easter weekend in 1980. Farming in this part of the country rarely provides enough income to support a family, and like most landowners I met in the oil patch, Richard held a second job, not retiring until 2006. Brenda worked part-time.

We arrived at a spot that afforded a view of the White Earth River, a narrow stream that winds through the Jorgensons' best farmland. The valley floor is where a company called Alliance Pipeline plans to locate a 12-inch, high-pressure gas conduit that would connect an existing gas-processing plant in Tioga to its main line some 80 miles away. Today is supposed to be the last day company surveyors will traipse around the ranch. The Jorgensons and several of their neighbors vehemently oppose the project. "I don't want a bomb in my backyard," Richard says, meaning a possible gas explosion. But Alliance has gone to court, threatening to



HELPING IN TIMES OF
ACCIDENTAL INJURY
OR DEATH.
Over 40 attorneys strong.

VOGEL
LAW FIRM

NEUMAN



LEWIS AND CLARK TRAIL



Sometimes western North Dakota seems like a truck jamboree featuring small towns with big-city traffic and fleets of semis barreling down gravel roads in farm country. For many longtime residents, driving to the store or church has turned into an unpleasant—and hazardous—undertaking.

KENWORTH

Becky Johnston and her teenage son Tyler (aiming a toy gun) aren't happy about leaving this Williston apartment complex. But like her neighbors, Johnston, a single mother, had no choice. An oil company bought the building to house workers, then evicted everyone. Across the oil patch, rents have increased up to fivefold, displacing people on low and fixed incomes.





2021

Catastrophic well-casing failures can happen at any time. The EPA is now investigating a 2011 blowout during fracking in a well near Killdeer that pierced the aquifer the town relies on.

use eminent domain, the controversial process by which private property can be seized in the name of a larger public good, in this instance, providing energy the U.S. demands.

While the Jorgensons fight to retain control of their bottomland, they're already living with the intrusive consequences of drilling. Eight hundred feet from their house a Petro-Hunt pump jack runs day and night, with the attendant noise, traffic, and contamination risks. They had no say. North Dakota allows landowners to separate surface rights from mineral rights, and during hard times some have been tempted to sell or trade the latter—for, say, needed equipment, like a new tractor. Richard's father had purchased a thousand acres from someone who didn't tell him he had sold the mineral rights—in five-acre parcels—to people all over the country. Further complicating the picture, the rights have since been bequeathed many times. After poring over records at the county courthouse, Brenda discovered to her horror that 110 strangers owned the minerals beneath the 40 acres surrounding her house. If a petroleum company can persuade 51 percent of mineral rights owners to agree—and given that they will make money, perhaps lots of it, without taking any risk, they usually do—it can drill on land that doesn't belong to them.

Perhaps farsighted action on the part of the

state legislature could have corrected this bizarre arrangement, but now the minerals leasing and exploration phase is largely over in western North Dakota, giving people who don't live and work on the land the power to dictate the fate of many who do. This predicament bears out a larger truth: Benefits from the oil boom are being widely dispersed. To be sure, local landowners who have retained mineral rights can earn a great deal of money from leasing. But much more wealth is leaving the region. Truck drivers like Connell and other temporary workers are paying down debts in their home states. Profits are flowing to oil company executives living in Canada, Texas, and Oklahoma, as well as to shareholders everywhere. The costs, by contrast, are localized. Taking the bad with the good may indeed be inescapable, even if the good isn't good for long and the "public good" often favors private interests. But in western North Dakota the bad must be borne largely by the long-term residents. They have the most to lose, and any fair calculation of risk would make their interests paramount.

Last August, Connell spent a day hauling oil pipe on an 18-wheel flatbed. She relished the chance to try something new. A "huge guy" at the storage yard held her by the waist while showing her the proper way to tie down a load. "He was awesome," she says. Becoming a badass pipe hauler would be a prudent move, because the next stage of development in the Bakken will include replacing a large portion of the oil and water fleet with a regionwide network of gathering pipes. Governor Jack Dalrymple, hoping to reduce the negative effects of truck hauling and to lower oil transportation costs, has urged pipeline companies to build the network as fast as possible. He and other state officials envision 6,000 to 8,000 miles of feeder line being constructed for each of the four well products—flow back, which is the mix of fluids both natural and man-made that's used in fracking; sweet crude; natural gas; and salt water. That's enough pipe crisscrossing western North Dakota to encircle the planet.

The boom's permanent legacy will also

include several large pipelines for conveying oil out of the region, as many as 50,000 two-mile-deep oil wells, hundreds of waste-disposal wells, and an unknown number of waste-reprocessing and storage facilities. The depth of the shale formations and the intervening rock layers make it unlikely fracking fluids will migrate upward far enough to contaminate shallow aquifers. But no one knows for sure. This is the first time fracking has been used under these geologic circumstances. The more we experiment with underground drilling, the more we discover that “impermeable” layers can be surprisingly permeable and fractures in the rock can be interlinked in unexpected ways.

Of special concern are the hundreds of fracking components, some of which contain chemicals known to be or suspected of being carcinogenic or otherwise toxic. Increasing the likelihood of unwanted environmental effects is the so-called Halliburton loophole, named after the company that patented an early version of hydraulic fracturing. Passed during the Bush-Cheney Administration, the loophole exempts the oil and gas industry from the requirements of the Safe Drinking Water Act. What’s more, manufacturers and operators are not required to disclose all their ingredients, on the principle that trade secrets might be revealed. Even George P. Mitchell, the Texas wildcatter who pioneered the use of fracking, has called for more transparency and tighter regulation. In the absence of well-defined federal oversight, states are starting to assert control. In 2011 the North Dakota legislature passed a bill that said, in effect, fracking is safe, end of discussion.

Looking further ahead, it’s uncertain how long oil well casings and plugs will last. A recent U.S. Geological Survey study of decades-old wells in eastern Montana found plumes of salt water migrating into aquifers and private wells, rendering the water from them unfit for drinking. And catastrophic casing failures can happen at any time. The EPA is now investigating a 2011 blowout during fracking in a well near Killdeer that pierced the aquifer the town relies on. As for the thousands of miles of

gathering pipelines, they’re another immense experiment. Many different companies, some less careful than others, will be involved, but even well-built pipes leak and rupture. The state lacks the resources to oversee a construction project of this magnitude, and once a line is approved, decisions as to where the pipes will be located and how they’ll be monitored during their decades-long life span will be left to the landowners, or most likely the landowners’ descendants, and the pipeline company, assuming it’s still in business.

If the Bakken oil boom is a classic Greek drama, the second act is starting now, and the prairie chorus is once again issuing a warning.

Warming tied to extremes” read the headline in the July 11, 2012, issue of the *Minot Daily News*, a conservative paper in a conservative town on the eastern edge of the oil patch. Warming, meaning man-made climate change, and weather extremes, meaning events such as a recent record heat wave in Texas, part of a severe drought that afflicted much of the West and Midwest last year. So far western North Dakota has been spared drought, but agriculture survives there only because farmers and ranchers have strictly husbanded fresh water, of which there is precious little. Local landowners now worry that the oil industry will deplete their aquifers. They argue that the Missouri River, not groundwater, should be the primary source of water used in fracking. However that controversy is resolved, an oil boom is under way in a region that may yet suffer drought for decades—prolonged and intensified, according to recent studies, by the burning of fossil fuels. If the cliché that there’s no free lunch is true, then what’s the price of an all-you-can-eat buffet?

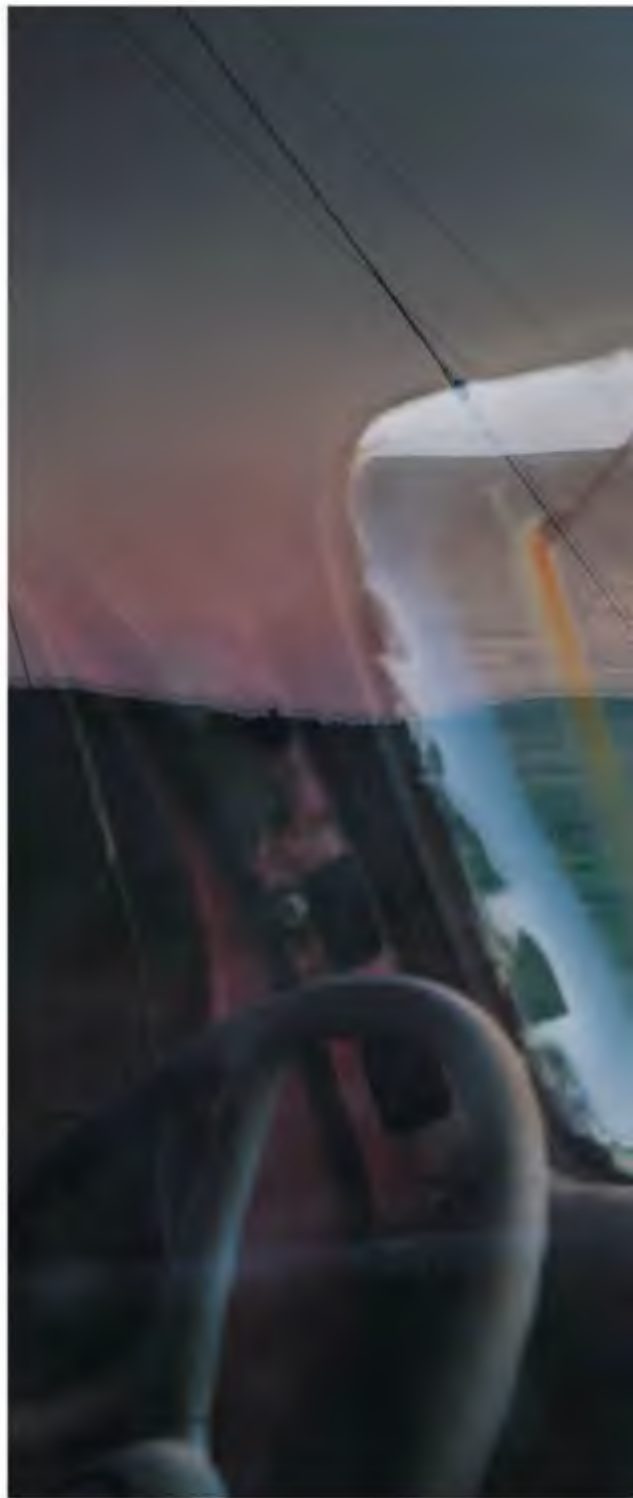
North Dakota is still in a position to parlay the boom into something lastingly beneficial. Of every dollar the oil industry earns, the state takes 11.5 cents, which produced revenues of more than two billion dollars from July 2011 to October 2012. One-third of that has been

deposited in a permanent fund, the interest on which cannot be touched until 2017. The rest is to be divided between the state and local jurisdictions. How the money will be spent remains uncertain, although plans are in the works to send some of it back to the oil patch for new roads, power lines, and municipal services like firefighting and law enforcement, and to help build schools, hospitals, and recreation facilities.

Another opportunity is at hand. Narayana Kocherlakota, an influential economist and president of the Federal Reserve Bank that oversees the district that includes North Dakota, told reporters in Williston last August that the boom is a onetime windfall that should be invested in long-range social programs and sustainable economic development. "How do we want western North Dakota to look in 20 years?" he asked.

To believe the old lifestyle will survive intact is to ignore the wrenching changes that have already reshaped this corner of the prairie. Even so, the state could use its oil bonanza to finally free itself from its boom-bust history by taking advantage of a natural resource both abundant and inexhaustible—the ever present wind. North Dakota's wind resource is ranked sixth in the country, according to the American Wind Energy Association, which helps explain why in 2010 Google chose the state for its first investment in commercial-scale wind farms.

Meanwhile, for a generation to come, and maybe longer, plenty of jobs will be available for roughnecks, construction workers, and truck drivers. To someone like Susan Connell, riding a roller coaster of mini-booms is better than the alternative. Besides the money, even though it fluctuates greatly, and the pride she takes in what she does, she says there are intangibles she's come to value. "I'm on a well, it's night, I'm alone." Stars overhead, gas flares in the distance, maybe the far-off cry of a coyote. Connell's standing on the catwalk, high above the ground, opening the hatch on a tank of clear salt water that came from thousands of feet beneath the surface, in the middle of the continent. She leans forward and breathes deeply. "It smells just like the ocean," she says. □





A natural gas flare illuminates an evening tableau of discarded vehicles and farm tools. The region is changing quickly and drastically, yielding consequences few foresaw. "We've set in motion an industrial juggernaut that probably can't be restrained," says Clay Jenkinson, a North Dakota historian. Now the juggernaut is influencing national energy policy and efforts to address climate change.

NIGHT

The sun vanishes. The pearl of a moon rises. Magic happens.

GARDENS





The gardens of Kykuit, at the Rockefeller estate in Sleepy Hollow, New York, were planned for day or night display. A row of lindens leads to the perfection of the Temple of Aphrodite.



月の丘

鳥さし



In Japan the nighttime viewing of cherry blossoms in spring, like these at Kyoto's Hirano Shrine, is a special event. "The cherries' only fault: the crowds that gather when they bloom," wrote Saigyō, a 12th-century poet.





When a freak freeze killed the orchid collection on his Mexican estate, English eccentric Edward James created Las Pozas, a garden with surreal follies like the concrete Bamboo Palace—durable and immune to the vagaries of weather.

By Cathy Newman

*Photographs by Diane Cook
and Len Jenshel*

*A starburst of night-blooming tropical
water lilies lifts from the pools of
Longwood Gardens in Pennsylvania.
The flowers open at dusk, then close
the following morning.*

In the nocturnal narrative of a garden at night,

the dramatis personae are wildly fragrant blooms that unfurl in darkness like jasmine, tuberose, gardenia; luna moths with wings the color of celadon; and scarab beetles iridescent as opals. The moon, which illuminates this stage, borrows its light from the sun. Its ashen light, the Greek philosophers knew, is reflected. A night garden invites reflection. Unlike the sun, the moon welcomes our gaze. We can wax poetic, wane with melancholy—howl, even—and admire the wonder of an obverse world where plants reach out, not to sunlight but to the faint glow flung to Earth by a diadem of stars.

Color is mostly irrelevant in a night garden. Because of how the eye sees, even the most incendiary reds and oranges turn into a monochrome of silver and grays under the waning moon. The retina, the sensitive lining of the eye's interior, is layered with photoreceptive cells called rods and cones. Rods, which detect the intensity of light, can sense low levels of illumination. But cones, which distinguish color, require a threshold of light higher than provided by the fading moon. In the absence of that threshold, color washes away. (The long exposure and sensitivity of digital imaging do what the retina cannot, which is why we see color in these photographs.)

Science, so informative, can be so rude. The perfume of flowers at night is nothing more than a ruse. "Gardens at night are more fragrant than gardens at day because most nocturnal pollinators have poor eyesight so must rely on their sense of smell to find flowers," says John Kress, curator of botany at the Smithsonian Institution's National Museum of Natural History. The world of night bloomers and their pollinators is an alternate universe finely honed through eons of evolutionary selection. Daytime pollinators like butterflies, birds, and bees rely on visual cues telegraphed by bright colors; night-shift workers like beetles and moths depend on fragrance, the

Cathy Newman wrote "East Side Story," about London's gateway district for immigrants, in the August issue. Diane Cook and Len Jenshel spent four years capturing the moody beauty of night gardens around the world.



luminescence of white petals, or—as in the echolocation of bats—the faint outlines of shape.

Enough. Better to linger in the dream-dusk of imagination and walk in the Pavilion Where the Moon Meets the Wind in the Garden of the Master of the Nets in Suzhou, China, or through Vita Sackville-West's White Garden at Sissinghurst Castle, England, frosted with white tulips, lilies, anemones, cream delphiniums, gray-white campanulas, and Iceberg and White Wings roses. They were planted, she wrote, in the hope that “the great ghostly barn-owl will sweep silently across a pale garden...in the twilight.” Or we may draw from the past and conjure the pleasure gardens built by Mogul rulers, cooled by pearls of water from marble fountains, canopied by trees heavy with pomegranates and oranges and painted with moonlight, like the fabled garden of Shalimar near Kashmir.

The word “paradise,” Elizabeth Moynihan, an architectural historian, says, can be traced to a transliteration of the Old Persian word *pairidaeza*, a walled garden. “The Paradise promised in the Koran consists of several terraces of gardens, each more splendid than the last,” she writes. The open-air palace of an Islamic garden was literally and figuratively paradise on Earth, a place to drink wine in silver pitchers, eat Kabul melons, and listen to poetry.

“Remote and closed as this soul of Islam remains,” recalled the French writer Vicomte Robert d’Humières after being entertained in the early 1900s by the brother of the maharaja of Jammu and Kashmir, “I doubt if we ever felt it nearer to us than that evening, among the fountains and the night-blossoms of the garden of Shalimar, while the full moon of August, from above the snows of the Tibetan frontier, poured down its clear light.”

If a garden is a reach to reclaim Eden, then perhaps our longing is best rewarded at night. The moon forgives the blight laid bare by sun. The cankered flower, the desiccated leaf, the rotted branch are swallowed by shadows, leaving only the illusion of perfection, silvered by starshine, gilded by moonlight. □



See time-lapse videos of the gardens in our digital editions.

Jade spires of bamboo flank a curving path on the grounds of Kodai-ji Temple in Kyoto. The murmur of wind filtering through a bamboo grove is cherished, and singled out as one of a hundred sounds the Japanese people want preserved.





An Islamic garden, it is said, is a palace without a roof. Enthralled with the art of Islam, heiress Doris Duke created Shangri La, her estate in Honolulu. The central courtyard, with its antique Persian tiles, separates public and private space.


WITH PERMISSION OF DORIS DUKE FOUNDATION FOR ISLAMIC ART





A fete like this, in the sumptuous gardens of Vaux-le-Vicomte, marked the beginning of the end for owner Nicolas Fouquet in 1661. Louis XIV came, saw, and coveted; he confiscated the property and imprisoned Fouquet.



A photograph of a garden at night. The scene is dominated by dense, dark foliage. In the foreground, large, dark lily pads are visible, some with small, light-colored flowers. A wooden fence runs across the middle ground, partially obscured by the plants. The background is filled with more trees and bushes, creating a sense of depth and enclosure. The overall atmosphere is quiet and somewhat mysterious due to the low light.

"I perhaps owe having become a painter to flowers," said French impressionist Claude Monet. He waited four years for his water garden at Giverny to bloom, before immortalizing it in paintings like "Water Lilies: Night Effect."







*To know Kykuit, said William Welles
Bosworth, who designed its gardens,
"one must experience...late evening
when all is peacefully eloquent."*





RETURN TO RIVER TOWN

In 1996 a Peace Corps volunteer arrived in Fuling, a sleepy town on the Yangtze, to teach English. He went back recently to find the landscape—and his former students—transformed.



Above: As a student, Liao Chaoli chose a bold English name, Mo Money. New buildings (left) tower over the Wu River.

BY PETER HESSLER

PHOTOGRAPHS BY ANASTASIA TAYLOR-LIND

T

here is excellent cell phone coverage at the bottom of the Yangtze River, although Huang Dejian is one of the few people who know this. He's the director of the new White Crane Ridge Underwater Museum, and today his phone rings constantly at a depth of 130 feet. The museum is the strangest sight in the city of Fuling—visitors enter via a 300-foot-long escalator encased in a steel tube, like a massive straw dipped into the muddy Yangtze.

"This is the most expensive museum in the Three Gorges region," Huang says, answering his phone again. The ringtone is a woman's voice that urgently repeats the phrase "Jia you—go, go, go, go, go!"

The last time I saw Huang, this was all dry land, and the \$34 million museum didn't exist, and the Three Gorges Dam was still under construction 280 miles downstream. I lived in Fuling from 1996 to 1998, when I was a Peace Corps volunteer at the local college. Back then the population was around 200,000, which was small by Chinese standards. Most people strongly

supported the dam, although they didn't talk about it much. It was scheduled for completion in 2009, which seemed an eternity in a place where so much was already happening. In China the reform era had begun in 1978, but it wasn't until the mid-1990s that free market ideas started to have a major impact on smaller cities like Fuling. Locals coped with overwhelming change: the end of government-assigned jobs, the sudden privatization of housing.

In those days the White Crane Ridge gave me a different perspective on time. The strip of sandstone emerged only in winter, when the water level dropped. Low-water season was treacherous for boatmen in ancient times, and somebody carved two fish into the side of the ridge. They served as a gauge, allowing pilots to anticipate the shoals and rapids downstream.

Locals associated the stone fish with good fortune, and it became a tradition to mark their annual emergence with a carved message. The earliest dated engraving was from A.D. 763, during the Tang dynasty, and eventually more than 30,000 characters decorated the sandstone. The calligraphy was stunning, and messages had the rhythm of incantations: "The water of the river retreats. The stone fish are seen. Next year there will be a bumper harvest."

In the 1990s admission to the ridge was three yuan, about 35 cents, which included a ride on a rickety sampan manned by an off-season fisherman. Huang Dejian used to sit on the ridge for hours, wrapped in a surplus People's Liberation Army overcoat. He would note the water level and tell stories about the most famous carvings. During one of my last visits, on January 30, 1998,

River Town is the first of three books by Peter Hessler based on the ten years he lived in China. This is documentary photographer Anastasia Taylor-Lind's first assignment for the magazine.



Watch an interview with author Peter Hessler on the iPad, Kindle Fire, or iPhone.



LANGUAGE LEARNING

Students practice foreign-language lessons by reciting aloud at a sports field on their new campus. In 1996, when Peter Hessler began teaching in Fuling, China had only three million college students; today there are more than 23 million.

FULING FELT SLEEPY and isolated. Foreigners were unheard of.



RESCUED FISH

Tourists pose beside a stone fish carved into the White Crane Ridge by Zhang Shifan, a local official, in 1813. The fish was removed before completion of the Three Gorges Dam to save it from being washed away.

the Yangtze was exactly two inches higher than it had been at the time of the first inscription in 763. Two inches in 1,235 years—that put the changes of the reform era in a new light.

Time moved differently on the river. The Yangtze remained a creature of cycles, even as life along the banks marched to the straight line of history and progress. And both kinds of time, natural and human, intersected at the White Crane Ridge every year. The river retreated; the words emerged; the messages and dates lined up neatly on the rock. And then the spring snowmelt would come, and the water would rise, and all that history would disappear once more beneath the timeless river.

Now that the dam is closed, the Yangtze no longer falls anywhere near the old levels. To protect against the high water of the reservoir, Fuling has surrounded itself with a dike that is nearly three miles long and 190 feet tall. The White Crane Ridge Museum is set into the side of this massive concrete wall. Today Huang Dejian takes me to the underwater viewing gallery,

where portholes face the submerged ridge. The scene is dreamlike: I recognize places where I once stood and engravings that I touched. But even familiar words seem to have a new meaning: “Pillar Rock in Midstream,” “The River Runs Forever.” What’s the significance of these inscriptions now that they lie 20 fathoms deep?

Huang Dejian smiles when I ask if he ever feels a sense of loss. His days of sitting on a cold Yangtze rock are long gone, and so is the People’s Liberation Army overcoat; today he wears a neat gray suit. In addition to handling the constant phone calls, he’s juggling my visit with that of a China Central Television film crew. “They weren’t able to do this at the Aswan Dam in Egypt,” he tells me, noting that Egyptian authorities had to move relics before they were flooded. “It makes me proud. I don’t have any feeling of loss when I come here; I feel like it’s a success. We were able to build the Three Gorges Dam and also successfully protect the White Crane Ridge.” And then Huang heads off to the television crew, and his cell phone rings its modern incantation: “Go, go, go, go, go!”

If I ate lunch downtown, I often drew a crowd of 30 spectators.



FULING SITS AT THE JUNCTION OF THE YANGTZE and the Wu Rivers, and in the mid-1990s it felt sleepy and isolated. There was no highway or rail line, and the Yangtze ferries took seven hours to reach Chongqing, the nearest large city. Foreigners were unheard of—if I ate lunch downtown, I often drew a crowd of 30 spectators. The city had one escalator, one nightclub, and no traffic lights. I didn't know anybody with a car. There were two cell phones at the college, and everyone could tell you who owned them: the party secretary, the highest Communist Party official on campus, and an art teacher who had taken a pioneering step into private business.

In those days Fuling Teachers College was only a three-year institution, which placed it near the bottom of Chinese higher education. But my students were grateful for the opportunity. Nearly all of them came from rural homes with little tradition of education; many had illiterate parents. And yet they majored in English—a remarkable step in a country that had been closed for much of the 20th century. Their essays spoke of obscurity and poverty, but there was also a great deal of hope: “My hometown is not famous because there aren't famous things and products and persons, and there aren't any famous scenes. My hometown is lacking of persons of ability...

I'll be a teacher, I'll try my best to train many persons of ability.”

“There is an old saying of China: ‘Dog loves house in spite of being poor; son loves mother in spite of being ugly.’ That [is] our feeling. Today we are working hard, and tomorrow we will do what we can for our country.”

My students taught me many things, including what it meant to come from the countryside, where the vast majority of Chinese lived at the beginning of the reform era. Since then an estimated 155 million people have migrated to the cities, and my students wrote movingly about relatives who struggled with this transition. They also taught me about the complexities of poverty in China. My students had little money, but they were optimistic, and they had opportunities; it was impossible to think of such people as poor. And Fuling itself was hard to define. The Three Gorges Dam could never have happened in a truly poor country—Beijing reports that the total investment was \$33 billion, although some unofficial estimates are significantly higher. But memories of recent poverty helped make the dam acceptable to locals, and I understood why they desired progress at all costs. My apartment was often without electricity for hours, and over-reliance on coal resulted in horrible pollution.





TOURIST DRAWS

The director of the White Crane Ridge Underwater Museum stands in the viewing gallery 130 feet beneath the surface of the Yangtze River. Downstream, tourists gaze at the Three Gorges Dam, which stretches for nearly a mile and a half. The dam is the largest concrete structure on Earth—five times as wide as the Hoover Dam.





TOO MANY CHOICES

Yang Fanglin (above) revisits her classroom from the mid-1990s, when as a student she took on the name Emily, after Emily Brontë. Back then the government assigned jobs to graduates. "You didn't have to make many decisions," she says. "Now there are so many options, which creates pressure." Most of the old campus, including the gymnasium, is unused and awaiting sale on the private market.

THE WRITER'S VANITY likes to imagine permanence, but Fuling

After finishing my Peace Corps assignment, I returned to my parents' home in Missouri and tried to record that moment in Fuling. After completing a 400-page manuscript—I called it *River Town*—I sent it out to agents and publishers, nearly all of whom rejected it. In the 1990s China hadn't yet entered the consciousness of most Americans. One editor said frankly, "We don't think anybody wants to read a book about China." But I eventually found a publisher, and that was when I began to worry about how locals would respond to the book.

The Chinese had always been extremely sensitive about how their country was portrayed by foreigners. Even in remote Fuling, I heard people speak angrily about books and films that they believed had emphasized Chinese poverty. When I began editing my manuscript, I sent a draft to a student named Emily, and most of her responses were positive. But sometimes she sounded a note of disappointment: "I think no one would like Fuling city after reading your story. But I can't complain, as everything you write about is the fact. I wish the city would be more attractive with time."

The balancing act seemed impossible. I wanted to show my affection for Fuling, but I also needed to be honest about the pollution, the dam, and the problems I sometimes had as a foreigner. In the end I accepted the possibility that I wouldn't be welcomed there again. But I hadn't imagined how fast the place would change. By the time *River Town* was published in early 2001, the city's first highway had been completed, rendering the Yangtze ferries obsolete. Two more new highways would follow, along with three train lines. Because of the Three Gorges project, large amounts of central government money flowed into Fuling, along with migrants from low-lying river towns that were being demolished. (All told, more than 1.4 million people were resettled.) In the span of a decade Fuling's urban population nearly doubled, and the college was transformed into a four-year institution with a new campus and a new name, Yangtze Normal University. The student body grew from 2,000 to more than 17,000,

part of the nation's massive expansion in higher education. Meanwhile, Americans began to take new interest in China, and *River Town* became a surprise best seller. I heard that an unofficial translation was commissioned in Fuling, with access limited to Communist Party cadres. But I never learned how the government reacted to the book.

This is my first visit back in more than five years, and it's the first time I've been invited to meet with a high-level official. At the Fuling District Government office, I wait for Vice-Director Liu Kangzhong, who has been preceded by an entourage of eight officials. The men sit in a line along one side of a conference table; I am alone on the other side. My attempts at small talk are unsuccessful. The room falls silent, and I realize that even in a Chinese boomtown there are moments when time moves very slowly.

Finally one of the cadres clears his throat. He says, "Have you sold a million copies of your book yet?"

This wasn't the question I expected, but it's easy to answer: No.

"Are they making a movie about it?"

I say that there has been some talk but nothing more.

"It would be hard to make a movie of that book," he says. "Fuling looks completely different from when you lived here. They wouldn't be able to find places to film that looked like it did in those days."

Everybody stands up when Vice-Director Liu arrives. He's in his early 50s but looks younger, a fine-featured man with gelled black hair. He distributes a round of Emperor cigarettes to his entourage, and then he recites the kind of statistics that you hear only in China. For the past five years Fuling's GDP has grown at an annual rate of 20 percent, and the city plans to add another 300,000 residents by 2015. A new factory district has attracted more than three dozen foreign-invested firms, including several that produce battery cells for cars and computers. All local cabs and buses now run on natural gas, in order to reduce pollution. To the west, the government is building a new satellite city,

reminds me that words are quicksilver. Meaning changes with every age.



FROM NOODLES TO TILES

When the Huang family's popular noodle restaurant was demolished as part of Fuling's redevelopment, they found a new trade. "In two years this will all be big buildings," Huang Xiaoqiang says. "And they'll need ceramic tiles."

which will be three times as large as the Fuling I remember.

"We've opened our eyes," Liu says. "When I was in school in the 1970s, we couldn't communicate with outsiders. China has been an open country for a while now, and we have a sense of what foreigners think. I've read some of your book." He continues: "Thank you for giving us *xuanchuan*." The word can be translated in different ways; sometimes it means "publicity," and sometimes it means "propaganda." Vice-Director Liu smiles and says, "Fuling is a good example of a Chinese city for Americans to know about."

The writer's vanity likes to imagine permanence, but Fuling reminds me that words are quicksilver. Their meaning changes with every age, every perspective—it's like the White Crane Ridge, whose inscriptions have a different significance now that they appear in an underwater museum. Today anybody who reads *River Town* knows that China has become economically powerful and that the Three Gorges

Dam is completed, and this changes the story. And I'll never know what the Fuling residents of 1998 would have thought of the book, because those people have also been transformed. There's a new confidence to urban Chinese; the outside world seems much less remote and threatening. And life has moved so fast that even the 1990s feels as nostalgic as a black-and-white photo. Recently Emily sent me an email: "With a distance of time, everything in the book turns out to be charming, even the dirty, tired flowers."

One evening I have dinner with Huang Xiaoqiang, his wife, Feng Xiaoqin, and their family, who used to own my favorite noodle restaurant. In 1998 Huang acquired his driver's license and told me he hoped to buy a car someday, which seemed impossible with his limited family income. But tonight he picks me up at my hotel in a new black Chinese BYD sedan. Huang drives exactly two blocks to a restaurant, and then we drive exactly two more blocks to his family home. These journeys may be short, but they



FORMER FARM BOY

Chen Zhenyong—Jimmy—grew up on a farm with only an eighth of an acre of land. “My parents would slaughter a pig when they had to pay school fees,”

he says. Now a teacher, he owns a car and four apartments and sends his daughter, Chen Hongli, to a private boarding school. In Fuling the Chongqing Department Store (right) caters to the growing class of urban consumers.





HUANG'S BROTHER-IN-LAW used a dictionary to read

provide ample time for Huang to make full use of his dashboard DVD player.

After dinner he insists on chauffeuring me back to my hotel. He tells me that his brother-in-law, who doesn't speak English, used a dictionary to read *River Town*. He went word by word; it took two years. "In your book you wrote that my biggest dream was to have a car," Huang says. "And this is the third one I've owned!"

I ask him what his biggest dream is now. On the dashboard screen, girls in miniskirts bounce to a song called "The Smiling Eyes of Love."

"There's nothing else I really need," he says at last. "Having a car was my big dream. We already have the important things now."

WHEN YOU LIVE in the Chinese interior, you realize how Beijing and Shanghai create an overly optimistic view of the country. But this is the first time I've wondered if Fuling might inspire a similar reaction. The city is under the jurisdiction of Chongqing Municipality, which receives more funding than other regions because of the dam. At the time of my visit, the top Chongqing official is Bo Xilai, who is known for having national ambitions. Along with his police chief, Wang Lijun, Bo has orchestrated a well-publicized attempt to crack down on crime and reform a corrupt police force. As part of this project, cities like Fuling have erected open-air police stations where officers must be available to the public at all times. This is hardly a new idea, but in China it feels revolutionary. I visit a few stations, which are busy handling the kind of problems that in the past often flared up as street fights. Everywhere I go, people tell me about Bo's reforms, and I realize that I've never been anywhere in China where people speak so positively about their government.

But you don't have to travel very far to hear a different story. Poverty and isolation no longer characterize Fuling, but smaller cities and villages still face these challenges. Most of my former students live in such places, where they teach English in middle schools and high schools. Their letters remind me how far China still has to go: "Dear Mr. Hessler: I am sorry

to tell a bad news. My town is called Yihe in Kaixian County in Chongqing. Two days ago, a big thunder hit my wife's village school. It killed 7 students and wounded 44 students... There used to be lightning rod... but the school can not afford it."

"One of my students' mothers worked [in a factory] in Guangdong for 10 years, she came [back] to Luzhou last month. She was cheated out of her bank card and code... She lost 45,000 yuan [more than \$7,200]. This was the money she saved in the past ten years. She wanted to use the money to build a new house and get prepared for her kids to go to college... She went back home and cried for many days, and two days later, she ate mouse poison and died in bed. What a bad things. It is hard to imagine what 45,000 means for a country woman."

During my visit, about 15 students return to Fuling for an impromptu reunion. They give updates on the classmates who, like so many Chinese of their generation, have migrated far from home. Several live in coastal boomtowns, and one does trade in India. Another is a Communist Party official in a Tibetan city, where he's in charge of xuanchuan. ("Publicity" to some, "propaganda" to others.) One woman hosted a popular radio show for years. Another man got fired from his teaching job, drifted out to the Tibetan Plateau, started a cab company, and became a millionaire. One student is in prison for corruption. William Jefferson Foster, a kid from a poor village who gave himself an impressive English name, has earned an excellent living by teaching English to the children of wealthy factory owners in the east. Emily now works in a Fuling elementary school, and she tells me about her cousin, a high school dropout who used to live in my building on campus. In those days he worked as a gardener. He subsequently went into construction, then contracting, then real estate; and now he has assets worth more than \$16 million.

The new mind-sets impress me even more than the material changes. At the college, teachers tell me that today's students, most of whom come from the new middle class, are more sophisticated. One evening I give a lecture, and during the

River Town. He went word by word; it took two years.



PRESIDENTIAL NAMESAKE

Dai Xiaohong, the son of illiterate farmers, became fluent in English and named himself William Jefferson Foster in honor of President Clinton. Here he gives private lessons in coastal Zhejiang Province, where students come from families of entrepreneurs.

question-and-answer session a freshman stands up and asks, “Do you think that China will ever be able to surpass the United States in democracy and freedom?” When I was a teacher, no student would have dared to ask such a thing in public. My answer is diplomatic but honest: “That depends on you and your generation.”

I also find that educated Chinese seem much more interested in analyzing their own society. Emily tells me that her cousin may be rich, but she’s noticed that money hasn’t made him happier. William observes that his younger relatives now migrate to destinations close to home rather than the coast, a sign that China’s boom is moving inland. William and his wife recently decided to violate the “planned birth” policy by having a second child. He made this decision after attending a funeral of a man with only one child. “I had to help his son lift the casket,” William says. “It made me think about what happens when we’re gone and my daughter is alone in the world. It’s better to have a sibling.”

His classmate Mo Money—another poor

kid who gave himself a bold English name—has succeeded as a teacher at an elite school in Chongqing. But he’s ambivalent about the relentless pressure of urban China. “Life is so competitive,” he says. “I think this is a special stage for China. The Chinese may have criticized other countries when they went through this—there was so much criticism of capitalist America in the old days. But now we are going through the same thing.”

FROM FULING I hitch a ride down the Yangtze with a student named Jimmy, who has a new SUV. I remember when this journey took two days by riverboat; now it’s a three-hour drive on a beautiful new highway. We pass the resettled cities of Yunyang and Fengjie, and then we arrive in new Wushan. The old town sites lie far beneath the Yangtze, and these fresh-built places appear prosperous. But in the past few years the region has suffered from landslides, and some believe that the constantly evaporating reservoir water has changed weather patterns. Students



NEW CASTING GROUND

On a part of the Yangtze where the water level has risen almost 400 feet, Huang Zongguo (above) and his father, Huang Yizhang, fish for yellow catfish. Beneath their net lies the former site of Jiaohuazi Valley, once known for its rich soil. "People used to joke that there were no bachelors in Jiaohuazi," Huang remembers. "Even the poorest man could afford a wife."





THE REGION HAS SUFFERED from landslides, and some believe

periodically send jarring updates: "Flood has come into our school, and it also came to the second floor of our teaching building. There were two big floods before this one. Now more and more people are doubting the Three Gorges project. Since it established, Chongqing and Sichuan have been natural disaster area."

"I want to tell you that my old family will be moved to somewhere because of the Three Gorges project. But I don't know where our villagers' homes will be... people here know it is because of landslide, but the government says it is for our good future."

Soon after my journey, China's State Council issues a surprisingly blunt statement admitting that the dam has "caused some urgent problems in terms of environmental protection, the prevention of geological hazards, and the welfare of the relocated communities." The council says that new safety measures are being taken, but it's a reminder that the Three Gorges Dam isn't truly finished and never will be, and that the cycles of the old Yangtze are still alive somewhere beneath the surface of the reservoir.

IN MARCH 2012 China's biggest scandal in decades erupts in Chongqing. Bo Xilai and Wang Lijun, once so widely praised, are suddenly purged from the Communist Party and accused of a spectacular series of crimes. Wang is found guilty of four offenses, including abuse of power and taking bribes. Bo is charged with a long list of offenses, ranging from "taking massive bribes" to "inappropriate sexual relationships," according to the official government news source. His wife, Gu Kailai, is convicted of the most shocking crime of all: the murder of a British businessman.

Across China, Bo and Wang are portrayed as the nation's worst villains. But many people in the Chongqing region are sorry to see the officials go. One student told me that in the early stages of the scandal, when preliminary reports said that Wang would be demoted to handling municipal education, teachers in her Chongqing school became worried. For years they had embezzled money from the students' lunch fees, and now they feared that Wang would clean up

the schools. As far as my student was concerned, corruption was endemic at all levels, but at least Bo and Wang had made some changes. "Wang gave people a sense of safety and Bo gave us hope," she wrote. "They were not perfect, but they really did something."

In the end Wang did not receive the demotion; instead he was sentenced to 15 years in prison. My student updated me on the dirty lunch fees: "We got the extra money when it was confirmed that Wang wouldn't come back."

MY LAST STOP is Wushan, where I call a number for the first time in eight years. I don't expect success: In fast-changing places no one keeps a phone number for long. But Huang Zongming answers, and soon I'm sitting on his boat. Zongming and his brother Zongguo are fishermen; I watched them move out of their homes in June 2003, when the first stage of the dam was completed. During that week the Yangtze flooded the entire district, and I felt certain that the brothers' lives were being irrevocably changed.

But now I discover that they are the only people I know who remain virtually the same. The government paid for a new house on the banks of the Daning River, a Yangtze tributary, but the brothers prefer to sleep on their boats, as they have done all their lives. They still make their own sampans, and their clothes are just as dirty as ever. They have not been anywhere interesting. Zongming, who dislikes all land transport, has still never ridden a train.

Today their boat cruises up the Daning, famous for its Little Three Gorges. The rapids were shallow at the time of my last visit; now the placid water is more than 300 feet deep, with new bays and inlets that cover former farmland. I ask Zongming what he thinks of the dam. He says, "The river looked better in the old days."

And that's all he has to say—the simplest analysis I've heard. The brothers tell me there's still good fishing upstream, where the rapids are low and fast. We head in that direction, and I imagine one final incantation: The weather will be perfect, the fish abundant. The river runs forever. □


that the evaporating reservoir water has changed weather patterns.



FLOATING FAMILY

Huang Zongguo's children play on the family fishing boat near Wushan. Like many rural Chinese, Huang violated the nation's planned-birth policy and paid a fine of \$1,500. "We still have the old thinking," he says. "Two are better than one."




THE NEW AGE OF  EXPLORATION

AN EXCLUSIVE
LOOK AT
BONOBOS
THE
LEFT
BANK
APE

A young female bonobo relaxes in the forest at Lui Kotale in the Democratic Republic of the Congo. Her lips are orange from eating clay, probably to counter plant toxins in her diet.





A mother known as Paula carries her tiny daughter, Prisca. As she approaches adulthood, Prisca will likely disperse to another bonobo community. Sons retain long-term bonds with their mothers.



By David Quammen

Photographs by Christian Ziegler

In a remote forest sector of the Democratic Republic of the Congo, along the north bank of the Luo River, 50 miles by dirt trail from the nearest grass airstrip, lies the Wamba research camp, a place that's quietly renowned in the annals of primatology. Wamba was founded in 1974 by a Japanese primatologist named Takayoshi Kano for the study of the bonobo, *Pan paniscus*, a species of simian unlike any other.

The bonobo, in case you haven't heard, carries a reputation as the "make love, not war" member of the ape lineage, far lustier and less bellicose than its close cousin, the chimpanzee. Modern studies of zoo populations by the Dutch-American biologist Frans de Waal and others have documented its easy, pervasive sexuality and its propensity for amicable bonding (especially among females), in contrast with chimpanzee dominance battles (especially among males) and intergroup warfare. But the bonobo's behavior in the wild has been harder to know, and Takayoshi Kano, operating out of the Primate Research Institute of Kyoto University, was among the first scientists aspiring to study it there. Apart from several interruptions, including a hiatus during the Congo wars of 1996-2002, observations at Wamba have continued ever since.

Early one morning I followed a researcher named Tetsuya Sakamaki, also from Kyoto University, into the forest. Promptly I saw things that, according to the popular image of the species, I might not have expected. Bonobos quarreled. They hunted for meat. They went hours at

a stretch without having sex. This was the animal so renowned for its lubricious, pacific social life?

As Sakamaki and I watched a party of bonobos feeding on the fruits of a *boleka* tree—small, grapelike morsels with papery husks—he identified the individuals by name. That female there, with the sexual swelling, we call her Nova, he said. She last gave birth in 2008; the gaudy inflation of her genital area, like a pink sofa cushion taped to her rump, advertised her readiness to breed again. This female is Nao, he said, very old, very senior. Nao has two daughters, of which the elder has so far remained in this group. And that female there, that's Kiku, also very senior, with three sons in the group. One of those sons is Nobita—easy to identify, Sakamaki explained, by his great size and the digits missing from his right hand and both feet and by the blackness of his testes. Missing digits suggest a mishap in a snare, not unusual for bonobos facing the hazards of human proximity. Nobita seems to be the alpha male, insofar as bonobo groups recognize alpha males.

By now we had followed the bonobos into a grove of musanga trees, and they were stuffing their mouths with fruit, pulpy and green. Suddenly a screechy altercation broke out between

 THE NEW AGE OF EXPLORATION is a yearlong series of articles celebrating *National Geographic* at 125.



The bonobo, once called the pygmy chimpanzee, is a unique species of ape, native only to forests on the left bank of the Congo River. Recent research casts new light on their sexual and other behavior.

Nobita and another male, Jiro. Kiku, Nobita's elderly mother, charged over to support her son. Cowed by the two of them, Jiro retreated. He sulked in a nearby tree. It's interesting, Sakamaki noted, that Nobita is the largest male in this group, and yet his mother helps him in a fight. Even a high-ranking adult male such as Nobita seems to hold his status partly on the merits of his mama.

Forty minutes later, when the screeching began again, Sakamaki drew my attention to the focus of excitement: an anomalure (a gliding rodent, like a flying squirrel), scrambling for its life on a tree trunk while several bonobos converged around it. As the bonobos came closer, the anomalure launched itself into space and glided away. Then we noticed a second one, clinging secretively to the east side of another large bole while a bonobo named Jeudi sat clueless just 15 feet to the west. This anomalure, pink eared and pale eyed, held its place on the bark more patiently, frozen, not giving itself away. Within a moment,

though, other bonobos spotted it, and the group closed in, shrieking with predatory menace. One bonobo climbed upward, struggling to find grips. The anomalure skittered 20 feet higher, ascending as easily as a gecko on a wall. When it was entirely surrounded with bloodthirsty apes, the little rodent launched itself and sailed away through the limbs and undergrowth to safety. We never even saw where it hit the ground; neither did the bonobos. Wow, I thought. Nicely done.

"Hunting behavior—it's very rare," said Sakamaki. "So you are very lucky."

Not yet noon on my first day at Wamba, and already my notion of bonobos had been confounded with realities, contrasts, and complications.

BONOBOS HAVE BEEN confounding people ever since they first came to scientific attention. Back

Montana-based David Quammen writes frequently about evolution. Panama-based Christian Ziegler specializes in nature photography.



MYSTERIES OF KINSHIP

Bonobos and chimps are the closest of cousins. Why do they behave so differently? The dividing Congo River holds clues.



Adult male



Adult male

Physical Traits

From a common ancestor, bonobos and chimps had become distinct species by about 900,000 years ago. Of similar height, they have different body proportions. Bonobos are more slender, with longer legs and smaller heads, brow ridges, and ears.

Bonobo *Pan paniscus*

Average male
100 lbs
4.3 feet tall

Female
74 lbs
4.2 feet tall



Female



Males



Female

Chimpanzee *Pan troglodytes*

Average male
132 lbs
4.4 feet tall

Female
93 lbs
4.1 feet tall

Females share power



Conflicts resolved with sex



Strong female bonding



Dramatically Different Societies

In bonobo communities females share power with their sons and can dominate. Chimp communities are led by an alpha male that gains and keeps his position through intimidation.



Males share power



Conflicts settled violently



Strong male coalitions

ART: FERNANDO G. BAPTISTA, NGM STAFF, TONY SCHICK
 SOURCES: FRANS DE WAAL, EMORY UNIVERSITY; OWEN LOVEJOY, KENT STATE UNIVERSITY; MELANIE MCCOLLUM, UNIVERSITY OF VIRGINIA; ADRIENNE L. ZIHLMAN, UNIVERSITY OF CALIFORNIA, SANTA CRUZ



Congo River Divide

The Congo River clearly separates bonobos from chimps. But their common ancestor would have lived on both sides. One theory about why they became two species points to the curious distribution of gorillas, which, like chimps, now live only on the right bank.

Bonobos

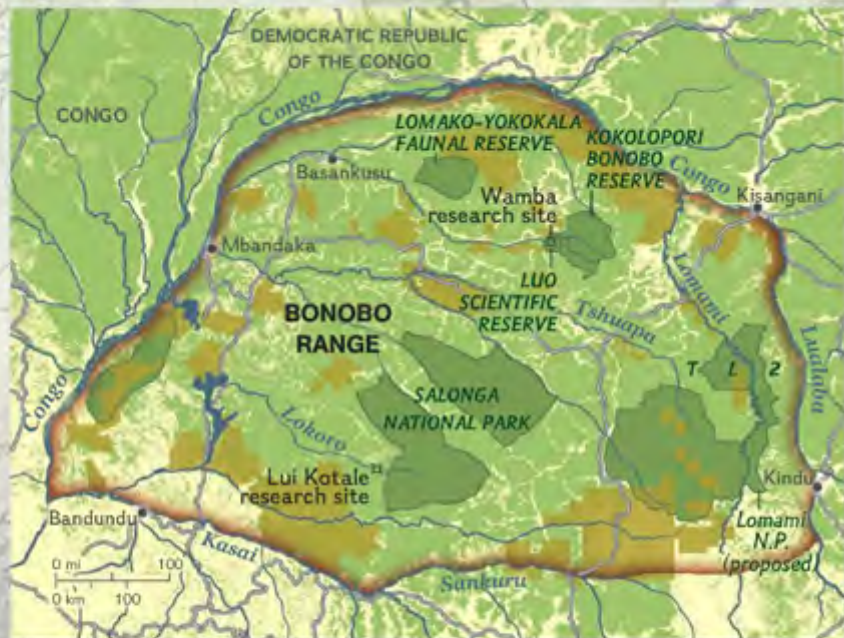
Without competition from gorillas for food, one theory holds, ancestors on the left bank of the Congo developed the less aggressive behavior of today's bonobos.

Chimpanzees

Another theory suggests that the ancestor of chimps and bonobos was already acting like a bonobo. Chimps are the ones that underwent changes, including learning to use tools, a behavior not yet seen in wild bonobos.

Gorillas

If gorillas had once lived on the left bank, they would have died out in an ancient dry era, when their main plant food temporarily vanished. Higher elevations on the right bank would have still supported the plants.



The Future of Bonobos

Population estimates range from only 15,000 to 20,000, and the numbers are falling. Illegal hunting for bush meat is the greatest threat, along with deforestation and a growing human population.

- Remaining primary forest habitat
- Protected
- Threatened (logging and mining)
- Nonhabitat

in 1927 a Belgian zoologist named Henri Schouteden examined the skull and skin of a peculiar animal, supposedly an adult female chimpanzee, from the Belgian Congo. The skull, he reported, was “*curieusement petit pour une bête de semblables dimensions*”—oddly small for an animal of such size. The following year a German zoologist, Ernst Schwarz, visited Schouteden’s museum and measured that skull as well as two others, concluding that they must represent a distinct form of chimp, unique to the south side—the left bank—of the Congo River. Schwarz announced his discovery in a paper titled “Le Chimpanzé de la Rive Gauche du Congo.” So from the beginning there was at least a subliminal association between the Left Bank culture at the center of the Francophone world—the bohemian artists and writers and philosophers of *la rive gauche* in Paris, south of the Seine—and this newly identified, unconventional Congolese ape. Soon after,

they mate in the missionary position, something virtually unknown among chimpanzees. But their sexiness isn’t just about mating. Most of those variations are sociosexual, meaning that they don’t entail copulation between an adult male and an adult female during her fertile period. The range of partners includes adults of the same sex, an adult with a juvenile of either sex, and two juveniles together. The range of activities includes mouth-to-mouth kissing, oral sex, genital caressing by hand, penis-fencing by two males, male-on-male mounting, and genito-genital rubbing (G-G rubbing is the shorthand term) by two estrous females, who moosh their swollen vulvas back and forth against each other in a spate of feverish sisterly cordiality. Usually there’s no orgasm culminating these activities. Their social purpose seems to be communication of various sorts: expression of goodwill, calming of excitement, greeting,

THE MAJOR DISTINCTIONS between bonobos and chimps

the left-bank ape was recognized as a full species and took its modern name, *Pan paniscus*.

Another label that fell upon it was “pygmy chimpanzee,” despite the fact that it’s not much littler than the common chimpanzee, the one already widely known, *Pan troglodytes*. The bonobo’s head is smaller in proportion to its body than a chimp’s, its physique more slender, its legs longer. But in overall size, both male and female adult bonobos fall generally within the same weight range as female chimps. Scientists today tend to avoid the term pygmy chimpanzee; “bonobo” better suggests that this creature is not a miniaturized version of something else.

The major distinctions between bonobos and chimps are behavioral, and the most conspicuous do involve sex. Both in captivity and in the wild, bonobos practice a remarkable diversity of sexual interactions. According to de Waal: “Whereas the chimpanzee shows little variation in the sexual act, bonobos behave as if they have read the Kama Sutra, performing every position and variation one can imagine.” For instance,

tension relief, bonding, solicitation of food sharing, and reconciliation. To that list of benefits we might also add sheer pleasure and (for the juveniles) instructional play. Varied and frequent and often nonchalant, sex is a widely applied social lubricant that helps keep bonobo politics amiable. De Waal again: “The chimpanzee resolves sexual issues with power; the bonobo resolves power issues with sex.”

Sexiness isn’t the only big difference between bonobos and chimps, though it’s probably linked to other differences, either as cause or as effect. Females, not males, hold the highest social rankings, which they seem to achieve by affable social networking (such as G-G rubbing) rather than by forming temporary alliances and fighting, as male chimpanzees do. Bonobo communities don’t wage violent wars against other bonobo communities adjacent to their territory. They forage during daytime in more stable and often larger parties, with sometimes as many as 15 or 20 individuals moving together from one source of food to another, and they cluster their



The vast Congo River, comprising many large and small channels, has been an impassable barrier between bonobos and their ape kin. Chimps and gorillas live only on the right bank, bonobos only on the left.

are behavioral, and the most conspicuous do involve sex.

nests at night, presumably for mutual security. Their diet, which is similar to the usual chimpanzee diet in most respects—fruit, leaves, a bit of animal protein when they can get it—differs in one signal way: Bonobos eat a lot of the herby vegetation that is abundant in all seasons—big reedy stuff like cornstalks and starchy tubers like arrowroot—which offers nutritious shoots and young leaves and pith inside the stems, rich in protein and sugars. Bonobos, then, have an almost inexhaustible supply of reliable munchies. So they don't experience lean times, hunger, and competition for food as acutely as chimpanzees do. That fact may have had important evolutionary implications.

Bonobos do share one distinction with chimpanzees: Together they are the two closest living relatives of *Homo sapiens*. Back about seven million years ago, somewhere in the forests of equatorial Africa, lived a kind of proto-ape that was both their direct ancestor and ours. Then our lineage diverged from theirs, and by about 900,000 years ago, those two apes had diverged

from each other. No one knows whether their last shared ancestor resembled a chimp, in anatomy and behavior, or a bonobo—but solving that uncertainty might say something about human origins too. Do we come from a long line of peace-loving, sex-happy, and female-dominant apes, or from a natural heritage of warfare, infanticide, and male dominance?

Also: What happened in evolutionary history to make *Pan paniscus* the unique creature it is?

RICHARD WRANGHAM has a hypothesis. Wrangham is a distinguished biological anthropologist and a professor in the Department of Human Evolutionary Biology at Harvard with more than four decades of experience studying primates in the wild. His work on chimpanzees dates back to his Ph.D. research at Tanzania's Gombe National Park in the early 1970s and continues at Kibale National Park in Uganda. He addressed the subject of bonobo origins in a 1993 journal paper and then in a popular 1996 book, *Demonic Males*, co-authored with Dale Peterson. The

Zoe shares a jungle fruit with her son Zizu and another youngster, while an adult male waits hopefully for a handout. Food sharing is part of bonobo social politics, reflecting nuances of status and alliances.







A female rests in a day nest at the Kokolopori Bonobo Reserve, established by the Bonobo Conservation Initiative in partnership with the local community and the Congo government. The reserve brings hope of tourism dollars.



crucial point in his hypothesis is the absence of gorillas, over the past one or two million years, from the left bank of the Congo River.

The reasons for that absence are uncertain, but the evolutionary consequences seem rather clear. On the river's right bank, where chimps and gorillas shared the forest, the gorillas ate what gorillas still eat, mainly herby vegetation, and the chimps ate a chimp diet, mainly fruit, tree leaves, and occasionally meat. On the left bank dwelled that other chimpish animal, privileged by circumstance to be free of gorilla competition. "And that's the formula," Wrangham told me by phone from his office at Harvard, "that makes a bonobo." The left-bank creatures, bolstering themselves on a rich chimpanzee diet when it was available and sustained by those staple gorilla foods when it wasn't, lived a steadier life; they weren't forced to break into small and unstable foraging groups, diverging, rejoining,

of frantically horny males on a short-term basis. She's continually attractive, continually ready. "That greatly reduces the importance to the males of competing for dominance and bullying the females." So the famed amity and sexiness of bonobo social life has, by Wrangham's hypothesis, an unexpected source: the availability of gorilla foods uneaten by gorillas.

And why are gorillas absent on the left bank? Wrangham suggested a scenario, speculative, he said, but plausible. Sometime after about 2.5 million years ago, severe drying seems to have hit central Africa. In the equatorial lowlands on both sides of the Congo, herby vegetation—gorilla habitat—shriveled away. Chimps could survive by finding fruit in riverside forests, but the right-bank gorillas were forced into highland refuges, such as the Virunga volcanoes in the northeastern part of the drainage and the Crystal Mountains in the west. On the left bank,

ON THE LEFT BANK dwelled that other chimpish animal,

scrambling for precious but patchily available foods, as right-bank chimps often are. And that fateful difference in food-finding strategy carried consequences for social behavior, Wrangham explained. The relative stability of foraging groups within a larger bonobo community means that vulnerable individuals usually have allies present at any given moment. This tends to dampen dominance battles and fighting. "Specifically," he added, "females have other females as well as males available to protect them from those that might want to bully them."

Another result of the foraging-group stability, he noted, involves the sexual rhythms of bonobo females. Unlike chimp females, they aren't obliged by circumstance to present themselves always as extremely attractive, extremely ready for mating with all possible males during just short, periodic windows of time. "If you are a bonobo," Wrangham said, and you live in a larger and more stable foraging group, "then you can afford to have a long period of sexual swelling." A bonobo female doesn't need to attract gaggles

though, there were no such highland refuges. The land is flat. So if gorillas had ever lived on that side, the Pleistocene drought may have killed them off.

BONOBO BEHAVIOR is exceptional among apes, and there are exceptions to the exceptions. You can't paint their portrait with a broad brush. No researchers have been more punctilious about this than Gottfried Hohmann and Barbara Fruth, a married couple based at the Max Planck Institute for Evolutionary Anthropology, in Leipzig, Germany, who have studied bonobos in the wild for more than two decades. Their work began in 1990 at a site called Lomako, in northern Congo, and they enjoyed uninterrupted field seasons until war started in 1998 and stopped everything for four years. Hohmann and Fruth then established a new field camp farther south, at a place known as Lui Kotale, in an excellent piece of forest just outside Salonga National Park. They arranged a compact with the local community within whose traditional



Bonobo youngsters such as Zizu, here playing with a sibling, are born black-faced, unlike chimps, which are born with pink faces that gradually darken. Bonobo limbs remain slender as they mature, not so thick and burly as chimps.

privileged by circumstance to be free of gorilla competition.

territory the forest lies: In exchange for a fee, the local people agreed not to hunt or cut trees at Lui Kotale.

To get there, you land at another grass airstrip, walk an hour into a village, pay your respects to the elders, and then keep walking for five more hours. You cross the Lokoro River in a dugout canoe, wade up a black-water stream, climb a bank, and find yourself in a neat, simple camp of thatched ramadas and tents, with two solar panels to power the computers.

Hohmann arrived back at this place, on a June day last year, like a man very glad to be in the forest again after too many months deskbound in Leipzig. He's a robust 60-year-old, blue-eyed and bony, long conditioned to the steeplechase rigors of field primatology, and if I hadn't been pushing to stay at his heels, the six-hour hike would have taken me seven.

One morning I rose with the early crew, two lean young volunteers named Tim Lewis-Bale and Sonja Trautmann. We reached the bonobo nests at 5:20 a.m., before the drowsy animals

began to stir. Their first act of the morning: a good piss. Lewis-Bale and Trautmann each stood beneath a nest tree, catching urine in a leaf. They pipetted this harvest into small vials, recorded the identity of each pisser, and then we were off on our morning chase.

That afternoon Hohmann and I sat beneath one of the thatch roofs discussing bonobo behavior. Few other researchers have seen bonobos in the act of predation, and those few reports generally involve small prey such as anomalures (only at Wamba) or baby duikers. Animal protein, insofar as bonobos get any, had seemed to come mainly from insects and millipedes. But Fruth and Hohmann reported nine cases of hunting by bonobos at Lomako, seven of which involved sizable duikers, usually grabbed by one bonobo, ripped apart at the belly while still alive, with the entrails eaten first, and the meat shared. More recently, here at Lui Kotale, they have seen another 21 successful predations, among which eight of the victims were mature duikers, one was a bush baby, and



Tranquil and protective, Zoe cuddles Zizu after nursing him. Male bonobos, unlike chimps, do not form same-sex coalitions to achieve power; from infancy to adulthood, a boy's best friend is his mother.



three were monkeys. Bonobos preying on other primates: “This is a regular part of the bonobo diet,” Hohmann said.

Sexiness, on the other hand, seemed to him less manifest than others, such as de Waal, had claimed. “I could show Frans some of the behaviors that he would not think are possible in bonobos,” Hohmann said. Infrequent sex, for instance. Yes, there’s a great diversity of sexual acts in the bonobo repertoire, but “a captive setting really amplifies all these behaviors. Bonobo behavior in the wild is different—must be different—because bonobos are very busy making their living, searching for food.”

Hohmann mentioned other points of conventional wisdom against which he and Fruth dissent, including the notion that bonobo society is held together as a genial sisterhood by female bonding (they consider mother-son bonding at least as important) and the notion that bonobos

imperial females), feels stressed by his complex situation. Bonobos eschew crude aggression and violence, but they’re not carefree; they use sociosexual behaviors, diverse and relatively frequent, as a means of conflict management. “This is what makes them different,” Hohmann said, “not that everything is peaceful.”

THE BONOBO is classified as endangered, and though protected by Congolese law, it continues to suffer from all-too-familiar problems, especially hunting for bush meat and habitat loss. Perhaps 15,000 to 20,000 bonobos remain in the wild, some of which are harbored within national parks and reserves, such as Salonga National Park and the Lomako-Yokokala Faunal Reserve. These “protected” areas may or may not provide effective security for bonobos and other wildlife, depending upon realities on the ground—for instance, whether or not guards have been

LIFE AS A BONOBO may be more stressful than it appears.

aren’t aggressive toward one another. Aggression may be rare and muted, he said, but that doesn’t make it unimportant. Consider how subtle human aggression can be. Consider how a single violent act, or merely a mean one, can stick in a person’s memory for years. “I think this is just what applies to bonobo behavior,” he said. Life as a bonobo may be more stressful than it appears. Evidence of hidden anxieties has begun emerging from a hormone study by one of his postdocs, Martin Surbeck.

Analyzing fecal and urine samples, such as the ones gathered that morning by Lewis-Bale and Trautmann, Surbeck has found a surprising pattern: high levels of cortisol, a stress-related hormone, in some bonobo males. Cortisol levels have been especially elevated among high-ranking males in the presence of estrous females. What does it imply? That a high-ranking bonobo male, walking a fine line between not enough machismo (which could cost him his status among males) and too much machismo (which could cost him his mating opportunities with

hired and trained, paid their salaries, and supplied with adequate weapons to face poachers. Congo suffered severely from its seven decades of Belgian colonialism, followed by three decades of Mobutu’s kleptocracy, followed by war; the context that frames all conservation efforts is institutional dysfunction. Among the hostages to this situation is the bonobo, a species native to no country in the world except Congo. If it doesn’t survive in the wild there, it will survive in the wild nowhere.

Two people who believe that it can survive are John and Terese Hart, conservationists who came originally to the Congo Basin in the early 1970s. Nowadays the Harts work with a young Congolese staff and a wide range of Congolese partners on a large project known as the TL2 Conservation Landscape, a region that straddles three rivers in eastern Congo and holds not just bonobos but also forest elephants, okapis, and a peculiar, newly discovered monkey called the lesula. Bonobos are still being poached at TL2, John told me, their carcasses often transported



The youngster Ulrich rides his mother, Uma, to the next foraging site. Bonobos spend much of their time on the ground, enjoying exclusive access to plant foods that on the right bank of the Congo are claimed by gorillas.

Evidence of anxieties has begun emerging from a hormone study.

to market by bicycle. With park status for part of TL2, antihunting regulations, support from local people, and enforcement at just a few checkpoints, he explained, that trade could be choked off. TL2 has magnificent potential, but the constraints are formidable, even for such an irrepressible, experienced man as John Hart.

In Kinshasa I joined John and Terese, and we flew into Kindu, a provincial capital in eastern Congo (and a jumping-off point to TL2) on the west bank of the Lualaba River, which defines the eastern limit of bonobo distribution. In Kindu we finally got approval for a little five-day expedition through TL2. Around four p.m.—late for a departure, but we were concerned not to lose another day—we climbed into a large dug-out canoe before the officials could change their minds. We were joined by two of the Harts' trusted Congolese colleagues, plus a visiting biologist, and a colonel and a soldier (both with Kalashnikovs) as our military escorts. There was also a man from the immigration directorate, assigned at the last minute to shadow

us. The immigration man wore street shoes and carried his change of shirt in a briefcase. We'll be out about 30 days, and you'll need to help us kill crocodiles for food, John teased him, as the outboard pushed us weakly away from Kindu, and we set our course midstream down the Lualaba.

The river was brown, flat, and a thousand yards wide. The sun, sinking low behind the dry-season haze, looked like a great bloody yolk. I watched a pair of palm-nut vultures pass overhead and then, to the east, a flock of fruit bats circling their roost. Dusk faded quickly to dark, and the river glowed sepia with reflection from a waxing crescent moon. The air cooled; we pulled on jackets. Hours later we grounded at a village on the left bank that marked our trailhead for this hike into bonobo country. It had to be the left bank, I knew. There were no bonobos, anywhere, on the right. □

■ **Society Grant** Research on bonobos was funded in part by your National Geographic Society membership.

Citizen Scientists

EXPERTS ONCE FEARED the nine-spotted ladybug was going extinct. That was until Peter Priolo, a volunteer ladybug hunter, saw one on a sunflower on Long Island, New York, two years ago. Priolo was thrilled. So was the Lost Ladybug Project, which is studying North American ladybugs with an assist from ordinary people—a practice known as crowdsourcing. The nine-spotted ladybug was once so common that a fifth grader successfully lobbied for it to become the New York State insect. But introduced species, it seems, have moved in and are eating the nine-spot's lunch. "In the future, crowdsourcing may pick up an invasive species before it's too late to get rid of it," says Cornell entomologist John Losey, the project's director.

Enlisting ordinary citizens isn't new to science. As early as the 1700s European bird surveys included reports from backyard birders. Amateur astronomers, weather-watchers, and other hobbyists have also made contributions. What's different today is the Internet, which has helped recruit hundreds of thousands of volunteers over the past decade. Choosing from projects like the ones at right, participants may share photos or answer a researcher's questions.

Social media are the latest way to get citizens excited about conservation. Coming soon: a Facebook app that lets people pick a whale shark to "like." Destined for viral fame is the specimen with a damaged tail that often turns up in waters off Western Australia. Researchers call him Stumpy the Shark.

—A. R. Williams

LACEWINGS

A California entomologist saw a Malaysian lacewing with an odd pattern on Flickr, a website for sharing photos, and identified it as a new species.



Semachrysa jade

10.5 MILLION

number of photos of animals and insects on Flickr

WHALE SHARKS

The Ecocean Whale Shark Photo-identification Library collects images shot by divers. Up to 65 feet long, whale sharks, the world's largest fish, are now hunted and vulnerable to extinction. But numbers aren't as dire as once thought.

320

sightings reported between 1828 and 1986

4,024

individual whale sharks identified in the Ecocean library photos

MOTHS

To help a University of Georgia professor classify his moth photos, Citizen Sort offers two online "games" that ask players questions about colors, patterns, and shapes.



Manduca sexta

46,634

photos of moths to identify

186,536

data points that will be created once all games are completed

LADYBUGS

Volunteers report sightings to the Lost Ladybug Project. They've established that the nine-spotted ladybug, New York's state insect, hasn't vanished from the area (but is still rare).



Coccinella novemnotata

29 YEARS

time between the last nine-spotted sighting in New York and the project's first in 2011

180

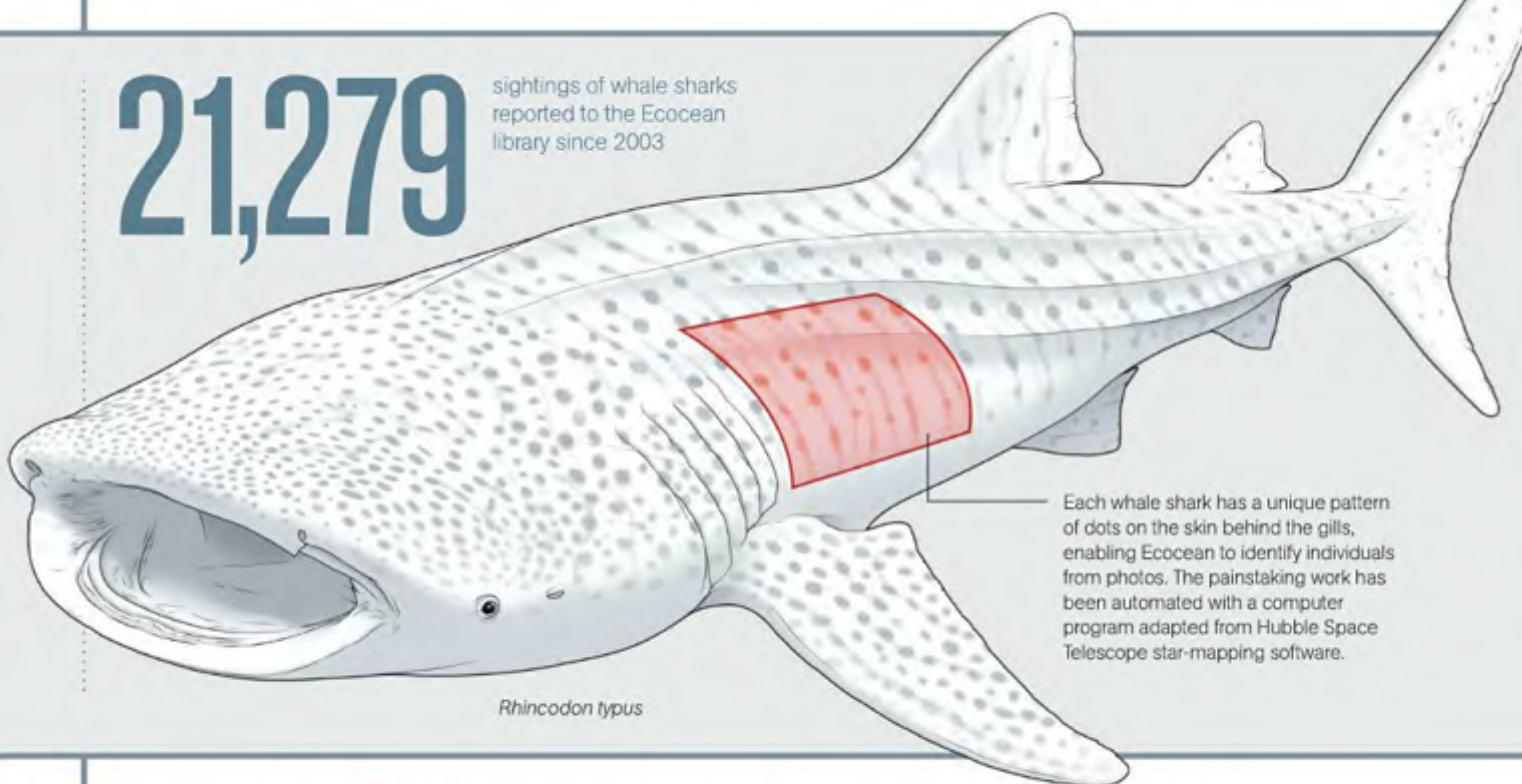
nine-spotted ladybugs seen in the U.S. and Canada since the project went online in 2008

475

species mapped on the project's website

21,279

sightings of whale sharks reported to the Ecocean library since 2003



Rhincodon typus

Each whale shark has a unique pattern of dots on the skin behind the gills, enabling Ecocean to identify individuals from photos. The painstaking work has been automated with a computer program adapted from Hubble Space Telescope star-mapping software.

ELEPHANTS

Photos from locals, guides, and tourists help ElephantVoices study the animals' behavior and movements in Kenya's Masai Mara region to better protect them.



Loxodonta africana

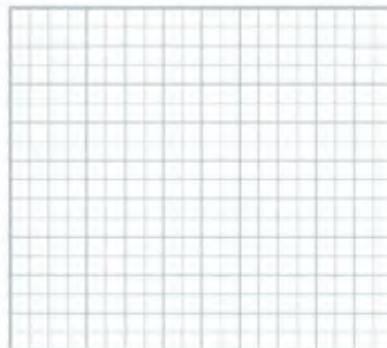
10 KILOMETER RADIUS

the daily distance a researcher typically travels from base camp while tracking elephants



9,000

square kilometers in the Masai Mara ecosystem



871

individual adult elephants whose photos have been uploaded to the ElephantVoices website since 2011

By Pat Walters Photograph by Marco Grob

Ice Water Diver

RHIAN WALLER studied deep-sea corals for ten years through portholes and on video feeds sent from robotic submarines more than 3,000 feet below the ocean's surface. The corals are the foundation of an ecosystem increasingly damaged by fishing nets, but scientists know very little about the slow-growing life-forms because they're so difficult to reach. A few years ago some of the same coral species turned up in shallow water in Alaska fjords. Shallow enough to dive in. The only problem for the 34-year-old University of Maine marine biologist: She didn't know how to dive.

Nearly freezing water doesn't seem like the best place to start scuba diving.

Oh yeah, it's intense. The water is usually 34 or 35 degrees Fahrenheit. Within five minutes of being in the water your head and hands are so numb you can't feel them. In the summer, when glaciers are melting, you get very fast currents. Visibility can be very poor too, because of all the sediment coming off the glaciers.

You're effectively submerged in ice water. Are you scared?

We're extremely careful. But I'd be lying if I said there haven't been hairy moments. On one dive visibility was so poor I couldn't even see my elbow. I was going down a fjord's vertical wall holding on to my buddy's tank when I let go to grab a sampling bag. I only looked away for a second, and he was gone. Suddenly I couldn't see anything—the wall, my hands, my feet. My ears started popping. I had to look for the bubbles to figure out which way was up.

But it's worth the risk?

Absolutely. It's hard for me to describe the feeling of actually swimming amongst a deep-sea species I'd only ever seen on a screen: To see these massive, six-foot-high red tree coral colonies sticking out from the wall, to stare at the polyps, to touch them and watch the tentacles recoil. I instantly thought of all the ecological work that could be done if you could go back to the same spot twice, which is all but impossible in the deep ocean. I'm still wading through the data, but it appears many of these corals reproduce on a significantly longer timescale than we thought, making them—and by extension the ecosystem—even more vulnerable to human impacts.



Marco Grob's video interview with Rhian Waller can be viewed on our digital editions.







A photograph of a person sitting on a utility pole against a clear blue sky. Several power lines stretch across the frame from the top left towards the bottom right. The background shows a dark treeline and a green field in the lower portion of the image.

the drones come home

Unmanned aircraft have proved their prowess against al Qaeda. Now they're poised to take off on the home front. Possible missions: patrolling borders, tracking perps, dusting crops. And maybe watching us all?

With eight arms spanning less than a yard, a German MikroKopter provides a stable camera platform for under \$5,000.

By John Horgan

Photographs by Joe McNally

at the edge of

a stubbly, dried-out alfalfa field outside Grand Junction, Colorado, Deputy Sheriff Derek Johnson, a stocky young man with a buzz cut, squints at a speck crawling across the brilliant, hazy sky. It's not a vulture or crow but a Falcon—a new brand of unmanned aerial vehicle, or drone, and Johnson is flying it. The sheriff's office here in Mesa County, a plateau of farms and ranches corralled by bone-hued mountains, is weighing the Falcon's potential for spotting lost hikers and criminals on the lam. A laptop on a table in front of Johnson shows the drone's flickering images of a nearby highway.

Standing behind Johnson, watching him watch the Falcon, is its designer, Chris Miser. Rock-jawed, arms crossed, sunglasses pushed atop his shaved head, Miser is a former Air Force captain who worked on military drones before quitting in 2007 to found his own company in Aurora, Colorado. The Falcon has an eight-foot wingspan but weighs just 9.5 pounds. Powered by an electric motor, it carries two swiveling cameras, visible and infrared, and a GPS-guided autopilot. Sophisticated enough that it can't be exported without a U.S. government license, the Falcon is roughly comparable, Miser says, to the Raven, a hand-launched military drone—but much cheaper. He plans to sell two drones and support equipment for about the price of a squad car.

Science writer John Horgan's most recent book is The End of War. Joe McNally likes technology; his photos of the electrical grid appeared in July 2010.

A law signed by President Barack Obama in February 2012 directs the Federal Aviation Administration (FAA) to throw American airspace wide open to drones by September 30, 2015. But for now Mesa County, with its empty skies, is one of only a few jurisdictions with an FAA permit to fly one. The sheriff's office has a three-foot-wide helicopter drone called a Draganflyer, which stays aloft for just 20 minutes.

The Falcon can fly for an hour, and it's easy to operate. "You just put in the coordinates, and it flies itself," says Benjamin Miller, who manages the unmanned aircraft program for the sheriff's office. To navigate, Johnson types the desired altitude and airspeed into the laptop and clicks targets on a digital map; the autopilot does the rest. To launch the Falcon, you simply hurl it into the air. An accelerometer switches on the propeller only after the bird has taken flight, so it won't slice the hand that launches it.

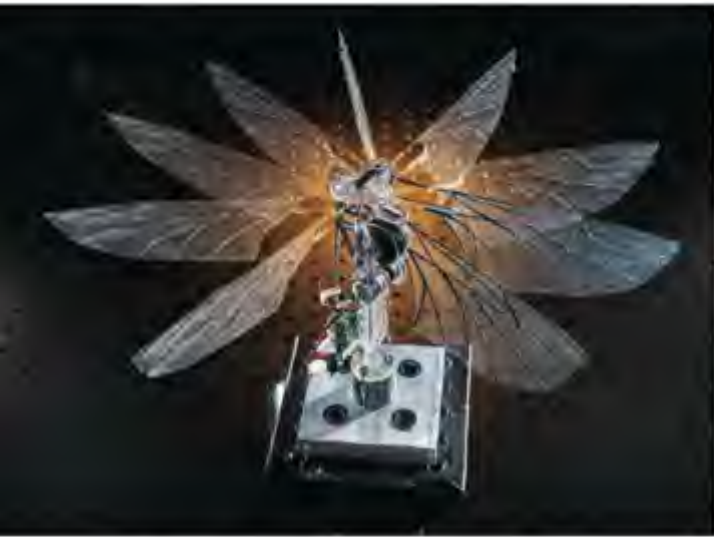
The stench from a nearby chicken-processing plant wafts over the alfalfa field. "Let's go ahead and tell it to land," Miser says to Johnson. After the deputy sheriff clicks on the laptop, the Falcon swoops lower, releases a neon orange parachute, and drifts gently to the ground, just yards from the spot Johnson clicked on. "The Raven can't do that," Miser says proudly.

Offspring of 9/11

A dozen years ago only two communities cared much about drones. One was hobbyists who flew radio-controlled planes and choppers for fun. The other was the military, which carried out surveillance missions with unmanned aircraft like the General Atomics Predator.

Then came 9/11, followed by the U.S. invasions of Afghanistan and Iraq, and drones rapidly

became an essential tool of the U.S. armed forces. The Pentagon armed the Predator and a larger unmanned surveillance plane, the Reaper, with missiles, so that their operators—sitting in offices in places like Nevada or New York—could destroy as well as spy on targets thousands of miles away. Aerospace firms churned out a host of smaller drones with increasingly clever



They flap fast, but can they take the torque? Two robo-moth wings, each three inches long, submit to a test at an Air Force lab in Ohio.

computer chips and keen sensors—cameras but also instruments that measure airborne chemicals, pathogens, radioactive materials.

The U.S. has deployed more than 11,000 military drones, up from fewer than 200 in 2002. They carry out a wide variety of missions while saving money and American lives. Within a generation they could replace most manned military aircraft, says John Pike, a defense expert at the think tank GlobalSecurity.org. Pike suspects that the F-35 Lightning II, now under development by Lockheed Martin, might be “the last fighter with an ejector seat, and might get converted into a drone itself.”

At least 50 other countries have drones, and some, notably China, Israel, and Iran, have their own manufacturers. Aviation firms—as well as university and government researchers—are

designing a flock of next-generation aircraft, ranging in size from robotic moths and hummingbirds to Boeing’s Phantom Eye, a hydrogen-fueled behemoth with a 150-foot wingspan that can cruise at 65,000 feet for up to four days.

More than a thousand companies, from tiny start-ups like Miser’s to major defense contractors, are now in the drone business—and some are trying to steer drones into the civilian world. Predators already help Customs and Border Protection agents spot smugglers and illegal immigrants sneaking into the U.S. NASA-operated Global Hawks record atmospheric data and peer into hurricanes. Drones have helped scientists gather data on volcanoes in Costa Rica, archaeological sites in Russia and Peru, and flooding in North Dakota.

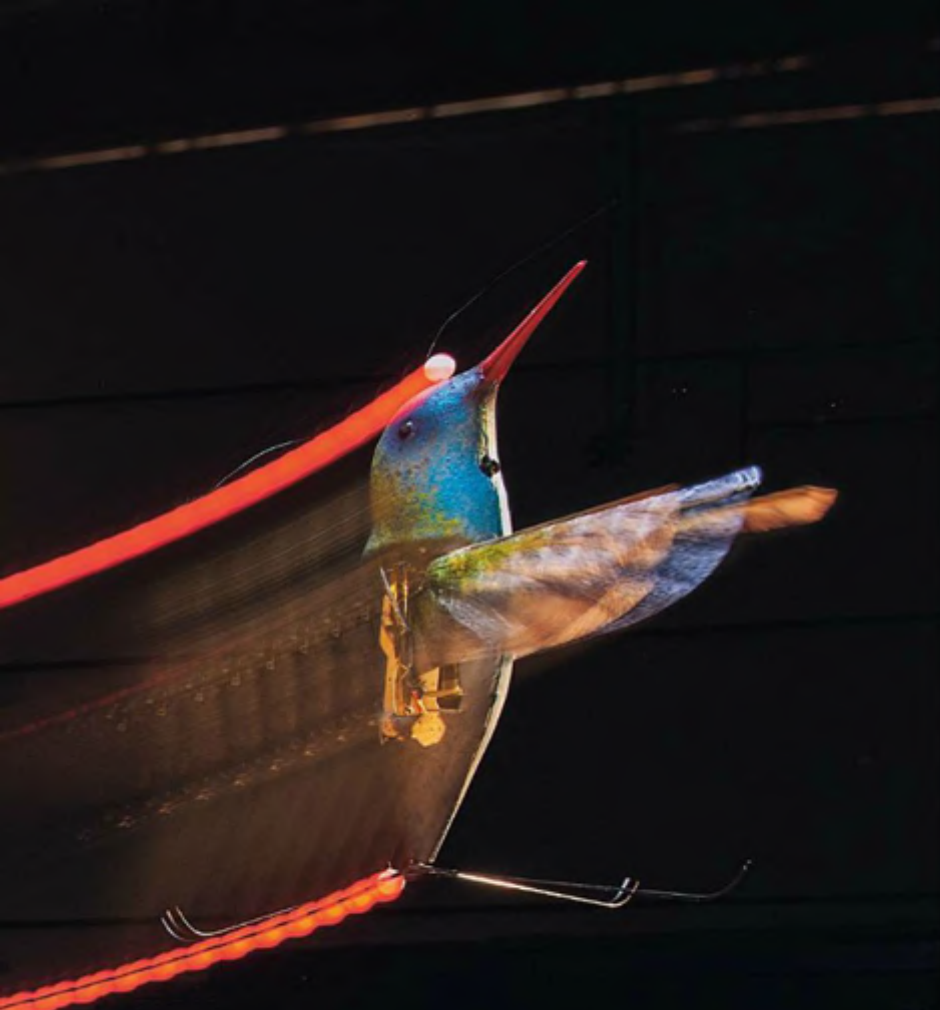
So far only a dozen police departments, including ones in Miami and Seattle, have applied to the FAA for permits to fly drones. But drone advocates—who generally prefer the term UAV, for unmanned aerial vehicle—say all 18,000 law enforcement agencies in the U.S. are potential customers. They hope UAVs will soon become essential too for agriculture (checking and spraying crops, finding lost cattle), journalism (scoping out public events or celebrity backyards), weather forecasting, traffic control. “The sky’s the limit, pun intended,” says Bill Borgia, an engineer at Lockheed Martin. “Once we get UAVs in the hands of potential users, they’ll think of lots of cool applications.”

The biggest obstacle, advocates say, is current FAA rules, which tightly restrict drone flights by private companies and government agencies (though not by individual hobbyists). Even with an FAA permit, operators can’t fly UAVs above 400 feet or near airports or other zones with heavy air traffic, and they must maintain visual contact with the drones. All that may change, though, under the new law, which requires the FAA to allow the “safe integration” of UAVs into U.S. airspace.

If the FAA relaxes its rules, says Mark Brown, the civilian market for drones—and especially small, low-cost, tactical drones—could soon dwarf military sales, which in 2011 totaled more



The Pentagon has asked for drones that "hide in



A time exposure traces the hover and swoop of a Nano Hummingbird, invented by Matthew Keennon and his team at AeroVironment in California. If it's ever deployed as a spy, the bird would fly without lights.



NANO HUMMINGBIRD

Width: 6.5 inches

Length: 4.5 inches

Weight: 0.66 ounce

Maximum altitude: trade secret

Maximum time aloft: 11 minutes

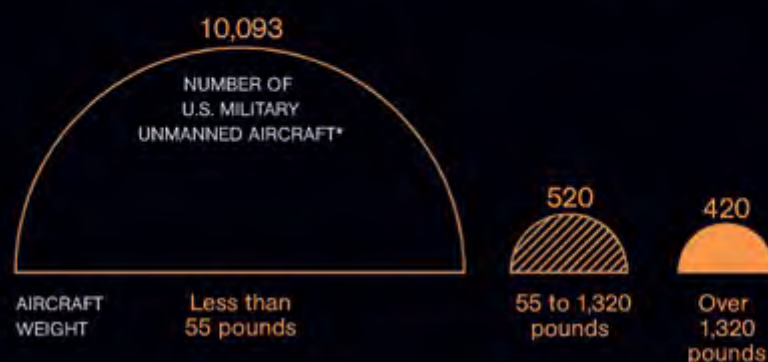
Maximum speed: 11 mph

plain sight," mimicking the behavior—and size—of bugs and birds.

The Military's Bleeding Edge

Northrop Grumman's X-47B, an unmanned aircraft being tested for the U.S. Navy, is designed to take off from an aircraft carrier, unleash two tons of weapons, and land again—on its own, with a preset mission, but without even a remote pilot. By sparing human war fighters “dull, dirty, or dangerous duty” (an industry buzz phrase), drones make some acts of war easier.

The U.S. Department of Defense currently maintains a roster of some 11,000 unmanned aircraft, ranging from lightweight surveillance drones to heavyweight tactical aircraft.



than three billion dollars. Brown, a former astronaut who is now an aerospace consultant in Dayton, Ohio, helps bring drone manufacturers and potential customers together. The success of military UAVs, he contends, has created “an appetite for more, more, more!” Brown’s Power-Point presentation is called “On the Threshold of a Dream.”

Dreaming in Dayton

Drone fever is especially palpable in Dayton, cradle of American aviation, home of the Wright brothers and of Wright-Patterson Air Force Base. Even before the recent recession, Dayton was struggling. Over the past decade several large companies, including General Motors, have shut down operations here. But Dayton’s airport is lined with advertisements for aerospace companies; an ad for the Predator Mission Aircrew Training System shows two men in flight suits staring stoically at a battery

of computer monitors. The city is dotted with drone entrepreneurs. “This is one of the few new industries with a chance to grow rapidly,” Brown says.

One of those entrepreneurs is Donald Smith, a bearish former Navy aircraft technician with ginger hair and a goatee. His firm, UA Vision, manufactures a delta-wing drone called the Spear. Made of polystyrene foam wrapped in woven carbon fiber or other fabrics, the Spear comes in several sizes; the smallest has a four-foot wingspan and weighs less than four pounds. It resembles a toy B-1 bomber. Smith sees it being used to keep track of pets, livestock, wildlife, even Alzheimer’s patients—anything or anyone equipped with radio-frequency identification tags that can be read remotely.

In the street outside the UA Vision factory a co-worker tosses the drone into the air, and Smith takes control of it with a handheld device. The drone swoops up and almost out of sight,

plummets, corkscrews, loops the loop, skims a deserted lot across the street, arcs back up, and then slows down until it seems to hover, motionless, above us. Smith grins at me. "This plane is fully aerobatic," he says.

A few miles away at Wright-Patterson stands the Air Force Institute of Technology, a center of military drone research. A bronze statue of a



bedraggled winged man, Icarus, adorns the entrance—a symbol both of aviation daring and of catastrophic navigation error. In one of the labs John Raquet, a balding, bespectacled civilian, is designing new navigation systems for drones.

GPS is vulnerable, he explains. Its signals can be blocked by buildings or deliberately jammed. In December 2011, when a CIA drone crashed in Iran, authorities there claimed they had diverted it by hacking its GPS. Raquet's team is working on a system that would allow a drone to also navigate visually, like a human pilot, using a camera paired with pattern-recognition software. The lab's goal, Raquet repeatedly emphasizes, is "systems that you can trust."

A drone equipped with his visual navigation system, Raquet says, might even recognize power lines and drain electricity from them with a "bat hook," recharging its batteries on the fly. (This would be stealing, so Raquet would not recommend it for civilians.) He demonstrates

the stunt for me with a square drone powered by rotors at each corner. On the first try the drone, buzzing like a nest of enraged hornets, flips over. On the second it crashes into a wall. "This demonstrates the need for trust," Raquet says with a strained smile. Finally the quad-rotor wobbles into the air and drapes a hook over a cable slung across the room.

Down the hall from Raquet's lab, Richard Cobb is trying to make drones that "hide in plain sight." DARPA, the Defense Advanced Research Projects Agency, has challenged researchers to build drones that mimic the size and behavior of bugs and birds. Cobb's answer is a robotic hawk moth, with wings made of carbon fiber and Mylar. Piezoelectric motors flap the wings 30 times a second, so rapidly they vanish in a blur. Fashioning bug-size drones that can stay aloft for more than a few minutes, though, will require enormous advances in battery technology. Cobb expects it to take more than a decade.

The Air Force has nonetheless already constructed a "micro-aviary" at Wright-Patterson for flight-testing small drones. It's a cavernous chamber—35 feet high and covering almost 4,000 square feet—with padded walls. Micro-aviary researchers, much of whose work is classified, decline to let me witness a flight test. But they do show me an animated video starring micro-UAVs that resemble winged, multi-legged bugs. The drones swarm through alleys, crawl across windowsills, and perch on power lines. One of them sneaks up on a scowling man holding a gun and shoots him in the head. The video concludes, "Unobtrusive, pervasive, lethal: micro air vehicles."

What, one might ask, will prevent terrorists and criminals from getting their hands on some kind of lethal drone? Although American officials rarely discuss the threat in public, they take it seriously. The militant Islamic group Hezbollah, based in Lebanon, says it has obtained drones from Iran. Last November a federal court sentenced a Massachusetts man to 17 years in prison for plotting to attack Washington, D.C., with drones loaded with C-4 explosives.

Exercises carried out by security agencies

A dozen U.S. police departments have sought permits to fly drones.



DRAGANFLY X6

Width: 36 inches

Length: 33 inches

Weight: 35 ounces

Maximum altitude: 8,000 feet*

Maximum time aloft: 20 minutes

Maximum speed: 30 mph

*ABOVE SEA LEVEL. SOURCE: DRAGANFLY



Thousands more are potential customers.



Deputy Sheriff Derek Johnson remotely pilots a Draganflyer X6 on a highway outside Grand Junction, Colorado. Mesa County has used drones since 2009 for search and rescue and to reconstruct crime scenes.

suggest that defending against small drones would be difficult. Under a program called Black Dart, a mini-drone two feet long tested defenses at a military range. A video from its onboard camera shows a puff of smoke in the distance, from which emerges a tiny dot that rapidly grows larger before whizzing harmlessly past: That was a surface-to-air missile missing its mark. In a second video an F-16 fighter plane races past the drone without spotting it.

The answer to the threat of drone attacks, some engineers say, is more drones. “The new field is counter-UAVs,” says Stephen Griffiths, an engineer for the Utah-based avionics firm Procerus Technologies. Artificial-vision systems designed by Procerus would enable one UAV to spot and destroy another, either by ramming it or shooting it down. “If you can dream it,” Griffiths says, “you can do it.” Eventually drones may become smart enough to operate autonomously, with minimal human supervision. But Griffiths believes the ultimate decision to attack will remain with humans.

Another Man's Nightmare

Even when controlled by skilled, well-intentioned operators, drones can pose a hazard—that’s what the FAA is concerned about. The safety record of military drones is not reassuring. Since 2001, according to the Air Force, its three main UAVs—the Predator, Global Hawk, and Reaper—have been involved in at least 120 “mishaps,” 76 of which destroyed the drone. The statistics don’t include drones operated by the other branches of the

military or the CIA. Nor do they include drone attacks that accidentally killed civilians or U.S. or allied troops.

Even some proponents insist that drones must become much more reliable before they’re ready for widespread deployment in U.S. airspace. “No one should begrudge the FAA its mission of assuring safety, even if it adds significant costs to



This “micro air vehicle” with four rotors, made by KMeI Robotics in Pennsylvania, can fly in swarms with its mates. The drones navigate autonomously, without a pilot.

UAVs,” says Richard Scudder, who runs a University of Dayton laboratory that tests prototypes. One serious accident, Scudder points out, such as a drone striking a child playing in her backyard, could set the industry back years. “If we screw the pooch with this technology now,” he says, “it’s going to be a real mess.”

A drone crashing into a backyard would be messy; a drone crashing into a commercial airliner could be much worse. In Dayton the firm Defense Research Associates (DRA) is working on a “sense and avoid” system that would be cheaper and more compact than radar, says DRA project manager Andrew White. The principle is simple: A camera detects an object that’s rapidly growing larger and sends a signal to the autopilot, which swerves the UAV out of harm’s way. The DRA device, White suggests, could prevent collisions like the one that occurred in 2011 in Afghanistan, when a 400-pound Shadow drone smashed into a C-130 Hercules transport plane. The C-130 managed to land safely with the drone poking out of its wing.

The prospect of American skies swarming with drones raises more than just safety concerns. It alarms privacy advocates as well. Infrared and radio-band sensors used by the military can peer through clouds and foliage and can even—more than one source tells me—detect people inside buildings. Commercially available sensors too are extraordinarily sensitive. In Colorado, Chris Miser detaches the infrared camera from the Falcon, points it at me, and asks me to place my hand on my chest for just a moment. Several seconds later the live image from the camera still registers the heat of my handprint on my T-shirt.

During the last few years of the U.S. occupation of Iraq, unmanned aircraft monitored Baghdad 24/7, turning the entire city into the equivalent of a convenience store crammed with security cameras. After a roadside bombing U.S. officials could run videos in reverse to track bombers back to their hideouts. This practice is called persistent surveillance. The American Civil Liberties Union (ACLU) worries that as drones become cheaper and more reliable, law

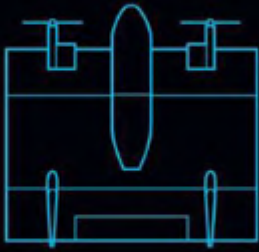
enforcement agencies may be tempted to carry out persistent surveillance of U.S. citizens. The Fourth Amendment to the Constitution protects Americans from “unreasonable searches and seizures,” but it’s not clear how courts will apply that to drones.

What Jay Stanley of the ACLU calls his “nightmare scenario” begins with drones supporting “mostly unobjectionable” police raids and chases. Soon, however, networks of linked drones and computers “gain the ability to automatically track multiple vehicles and bodies as they move around a city,” much as the cell phone network hands calls from one tower to the next. The nightmare climaxes with authorities combining drone video and cell phone tracking to build up databases of people’s routine comings and goings—databases they can then mine for suspicious behavior. Stanley’s nightmare doesn’t even include the possibility that police drones might be armed.

Who’s Driving?

The invention that escapes our control, proliferating whether or not it benefits humanity, has been a persistent fear of the industrial age—with good reason. Nuclear weapons are too easy an example; consider what cars have done to our landscape over the past century, and it’s fair to wonder who’s in the driver’s seat, them or us. Most people would say cars have, on the whole, benefited humanity. A century from now there may be the same agreement about drones, if we take steps early on to control the risks.

At the Mesa County sheriff’s office Benjamin Miller says he has no interest in armed drones. “I want to save lives, not take lives,” he says. Chris Miser expresses the same sentiment. When he was in the Air Force, he helped maintain and design lethal drones, including the Switchblade, which fits in a backpack and carries a grenade-size explosive. For the Falcon, Miser envisions lifesaving missions. He pictures it finding, say, a child who has wandered away from a campground. Successes like that, he says, would prove the Falcon’s value. They would help him “feel a lot better about what I’m doing.” □



AURORA SKATE

Width: 24 inches

Length: 19 inches

Weight: 35 ounces

Maximum altitude: 14,300 feet*

Maximum time aloft: 90 minutes

Maximum speed: 58 mph



Nimble enough to fly inside an abandoned factory, the Skate is made for reconnoitering urban landscapes—such as a 16th-century city in Peru (inset) surveyed by Vanderbilt University archaeologists.



NATIONAL GEOGRAPHIC ON TV



Alpha Dogs

At Vohne Liche Kennels in Denver, Indiana, Ken Licklider and his staff work under top security clearance to prepare dogs for jobs in all branches of the military. Soldiers (like this one, carrying his charge as part of an exercise) come here to train too. Watch them teach their dogs to sniff for bombs, jump from planes, and more this month on the National Geographic Channel.

LECTURE

JOURNEY TO VIETNAM When photographer Catherine Karnow first visited Vietnam in 1990, she saw poverty and postwar trauma but also beauty and nostalgia. Today her work captures the country's growing prosperity. Karnow's spring speaking dates are at nglive.org.

TRIP

SCHOOL'S OUT Spend part of your summer on a National Geographic Student Expedition. Designed for high school students, these trips offer the opportunity to work on field research projects, learn photography from our pros, and get involved in community service. See the destinations for this summer at ngstudentexpeditions.com/2013.



DVD

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EXHIBIT



AFGHAN TREASURE In the late 1980s a cache of ancient artifacts and art was covertly removed from the Kabul museum. Kept hidden for more than a decade, the priceless objects will soon go on display in Australia. Bronze Age gold, pieces from the Bactrian Hoard, and other items offer glimpses of the cultural history of Central Asia. The exhibit opens March 22 at the Melbourne Museum; visit museumvictoria.com.au/melbournemuseum.

BOOK

GO FOR A DRIVE This updated guide features scenic drives in all 50 states. The 300 routes range in length up to 700 miles, so you can hit the road for a few hours or a few weeks. Detailed descriptions, maps, and photos accompany each excursion. In stores March 5 (\$26.95).



The Zen of Petals A veil of wire protects this hallowed weeping cherry tree in Kyoto's Maruyama Park, where locals gather in spring to take in the blossoms. Daytime viewings are called *hanami*, nighttime ones *yozakura*. Shortly after the flowering peaked, Diane Cook and Len Jenshel—there to photograph the magic of gardens after dark—learned that her father's health was deteriorating. Preparing to go home, the couple paused to watch petals blowing off the trees, and found new meaning in Japan's custom of taking time to enjoy the short-lived blooms. —Luna Shyr



BEHIND THE LENS

This immense 40-foot tree is much revered in Japan. Why?

DC: Standing there is like going to a mountaintop in Tibet or India and finding this elder who's going to grant you wisdom. The tree has its own *sakuramori*—cherry-tree doctor—who tends to its care. The wires help keep birds off of it.

LJ: It's known as the elder or grandfather tree. It was transplanted in 1949 from a

seed of a nearly 200-year-old tree.

You said you found solace in the wisdom of the cherry trees. What wisdom was that?

DC: On the last day, before going to the airport, we went to get a last look.

It was breezy, and the cherry blossoms were starting to come down. I sat in this grove, and tears were just rolling down my face.

We fully understood then what the Japanese had been practicing for centuries—that in our busy lives we

need to make time to appreciate life's ephemeral nature.

LJ: Diane's father died shortly after our return. Life passes, we go on—it's part of the cycle of life. It didn't make the grief easier, but somehow I could place it in context.



Boom and Town A forest of derricks rises beyond a Signal Hill, California, neighborhood in this photo from the June 1941 *National Geographic*. Oil had been discovered there just 20 years earlier. The caption accompanying this photo notes: "If one man drills and strikes oil, his neighbor at once drills, too, lest the first drain the pool." Today the area's Long Beach oil field is much depleted, but it still yields more than a million barrels a year. According to John Huff, an engineer for California's Department of Conservation, extraction technology has moved on to more efficient pumping units. Huff's team at the Division of Oil, Gas, and Geothermal Resources placed this photo's scene at the corner of present-day Dawson Avenue and Village Way. Some of the houses pictured are still standing, but no derricks compete with the palm trees there anymore. —Margaret G. Zackowitz

🔗 **Flashback Archive** Find all the photos at ngm.com.

PHOTO: B. ANTHONY STEWART, NATIONAL GEOGRAPHIC STOCK

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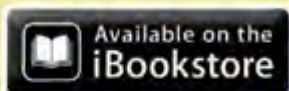
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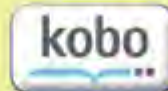


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